

AN ABSTRACT OF THE THESIS OF

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Title: A COMPARISON OF THREE METHODS OF TEACHING  
COLLEGE CHEMISTRY

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Abstract approved:

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Problem: To compare the effectiveness of three different methods of teaching chemistry at a community college.

Procedure: Three classes of college chemistry were taught using the traditional lecture-discussion with a typical text, a lecture-discussion using a programed text, and an individualized self-paced method.

The self-paced course was designed to allow the students to proceed only after they had mastered the material. The students used a programed text and had material presented on audio cassettes and dittoed pages of lecture notes. The students were free to listen to the tapes at any time and also to take the tests at the time they determined they were ready.

All three groups of students were tested with an American Chemical Society test at the completion of the three term sequence.

Conclusions: The results were analyzed by comparing the results with high school grade point averages by the statistical method of analysis of covariance.

The self-paced approach was shown to produce improved learning. The students using this approach consistently scored very high on the standardized test. One reason for this may be the greatly increased involvement in the business of learning by the students. The more active type of learning appears to be more effective.

The self-paced approach clearly solved the problems of scheduling which are normally quite prevalent in a small community college. The philosophy of self-pacing fits well with the philosophy of meeting the needs of the students. The class is much more available to all students than a class that is tied to an administratively determined schedule. The most negative aspects of the self-paced approach were the extreme amount of time required of the instructor and the small number of students who completed the sequence.

A Comparison of Three Methods of  
Teaching College Chemistry

by

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# A COMPARISON OF THREE METHODS OF TEACHING COLLEGE CHEMISTRY

## I. INTRODUCTION

Chemistry has been taught by lecture-discussion or lecture-recitation in combination with laboratory for the last fifty years. Very few attempts have been made to teach college chemistry by any other methods. Recently much experimental work has been attempted in teaching other subjects by different methods. It was decided to use different techniques and to compare the learning achieved by typical students when using these varying techniques. The three techniques chosen for study were traditional lecture-discussion, programed, and individualized self-paced. The individualized technique allowed the student to learn at any pace he was willing to maintain as long as he mastered each section before proceeding to the next section.

The study of chemistry has been fundamental to the educated person for the past fifty years but times change and so do people's values. Material comfort does not seem as centrally important as it once did. The awe of past generations for the wonders of chemistry was sincere but naive. We must not turn away from science now but must learn to use it more intelligently. We need a

generation of scientists who are committed to the wise use of their discoveries. Moreover we need a generation of non-scientists knowing enough about chemistry to anticipate the outcome of technical decisions. There has never been a time when it has been more important for the non-scientist to understand chemistry. There has never been a time when political and economic judgments are so likely to get us into scientific trouble. The goal of knowledge in chemistry as in any other area is control. In the past ignorance, if not bliss, was moderately harmless. Now it can be disastrous.

In the past most of the non-chemists who took a chemistry course came away with two general feelings: first that it was a very difficult subject and second that it was a subject that they would not remember for any period of time. Can college chemistry be taught in such a way as to increase the learning of the students? Does improved learning occur if chemistry is taught by a programmed procedure or by self-paced individualized instruction as opposed to the traditional lecture method?

What kind of educational experiences should be provided for non-science chemistry students? Should the aim be to provide them with a marketable skill or an added increment of general education? Should this

general education be a pale facsimile of a regular university school program or should it be a new kind of general education? Whatever the content, how could this reformed educational system spread respectability, quality, and prestige among its various parts? The current case has been made more complex by the increasingly dominant role of science and technology in the life of individuals and their societies. Can any job oriented kind of training which the schools are capable of providing keep pace with the world which is rapidly and ceaselessly being transformed by the impact of revolutionary developments in science and technology? The question not only haunts educators concerned with vocational and technical education in the secondary schools and community colleges, but it has also forced a reconsideration of new and enlarged educational aims upon general education itself. What is the proper role of mathematics and science at every level of education including adult education? The issue here is not merely the production of scientists and technicians but the production of a scientifically and technically literate people who can live safely and sanely in a new kind of world. Indeed, man's great achievements in science have added a new dimension to the controversy about the aims



of education. Education systems must undergo a shift of emphasis. The new stress must be not so much on producing an educated person but on producing an educable person who can learn and adapt himself efficiently all through his life to an environment that is ceaselessly changing.

In the development of any educational system, one must keep in mind the concern for accountability of the student, the teacher, the course, and the school. One of the methods of enhancing accountability is to design the course with the method of systems analysis. This allows continuous feedback for all parts and allows the experimenter to know the status of all parts at any particular point in time.

Coombs (1968) has pointed out that in applying a systems analysis as an aid to fashioning a strategy of action for increased learning, it will be rewarding to keep in view the several principles listed below. These principles can be a powerful working tool for reshaping and working an educational system in an almost infinite variety of ways.

1. The principle of individual differences. Students vary enormously in their individual aptitudes, rates of learning, and ways of learning. Hence each

will learn best when the means and conditions of learning are flexibly adapted to his pace and style.

2. The principle of self-instruction. Every student whatever his aptitudes has an inherent curiosity and capacity for learning a great deal on his own provided he is properly motivated and given access to the "stuff" of learning in attractive and digestible form.

3. The principle of combining human energy and physical resources. The work done by a human being can be greatly increased by placing more and better tools and technology at his disposal and teaching him to use these to the best advantage.

4. The principle of the economies of scale. Whenever expensive educational equipment and facilities are involved the costs per student are likely to decline without a loss of quality and effectiveness as things are done on a larger scale until the point where diseconomies of scale may set in. What may be prohibitively expensive on a small scale may be economically feasible on a large scale and may be the lowest cost approach.

5. The principle of division of labor. If people with differing kinds and degrees of special competence break a complex job into its component parts

and if each person then handles the parts that best match his competence each performs at his highest productivity and the overall result will be greater.

6. The principle of concentration and critical mass. It is wasteful to embark upon certain learning objectives unless they are going to be pursued beyond some minimum point of intensity and continuity short of which the effort will have little if any worthwhile "payoff".

7. The principle of optimizing. Whenever several different components are combined in a productive system it is never possible for every component to be used to its theoretical maximum productivity, but the optimum overall result will be achieved when the components are combined in such proportions as to use the scarcest and most expensive components most intensively and the cheaper and more abundant components less intensively.

These seven principles are all used in the method of teaching which has been called self-paced individualized instruction for mastery learning.

#### Need For The Study

The purpose of this study is to evaluate the effects of innovative practices upon the learning

achievement in college chemistry. The sequence of courses selected for the study is General Chemistry 201, 202, and 203 as taught at Central Oregon Community College. This sequence is designed primarily for the science oriented student who is not a chemistry major. Within the student population are included pre-engineering, pre-medical, pre-nursing, life science majors, and a relatively large number of students who are undecided about their major. Usually the undecided are contemplating scientific fields. The course has required a prerequisite of high school chemistry and a reasonable proficiency in mathematics. As with most community college classes the beginning backgrounds are extremely heterogeneous, from students with one year of "C" in high school chemistry to students who have completed two very successful years of high school chemistry. Mathematics backgrounds vary from students who are beginning calculus to students who are beginning intermediate algebra.

Not only do individuals enter with varying backgrounds but they learn at different rates. Even individual students will vary in their rate of learning depending upon the material being covered and various pressures being applied. Self-pacing should allow for variable individual rates.

The attrition rate in chemistry has been much too high with less than 50 per cent completing the entire year's sequence of courses. Many of the students who do complete the sequence appear to "slip through" without even a minimal knowledge of the fundamentals of chemistry. These are the students who in the future will say that they learned nothing from chemistry.

Chemistry teachers must find ways of making the subject more relevant and of increasing the retention of the knowledge. A more effective and thorough learning technique should improve retention. Is it necessary to have a teacher in attendance or can a course be prepared and the students allowed to proceed until the completion of the allotted tasks? Much of any college education could be acquired by a highly motivated and well disciplined learner with or without a teacher. However, practice and a continuous knowledge of results are still needed. Tests in the future should become a part of the learning process rather than a special occasion.

There is no question but that schools like industry will adapt to automation with a resulting reallocation of manpower and skills. The nature of students and learning being what they are, the probability is that few teachers will be displaced, but

in any situation where the device can instruct as effectively at a lower unit of cost it will be used. If the result is to provide greater learning with the same resources, a replacement of less competent teachers by those with a higher order of skill or a better provision for individual differences should be sufficient reason to utilize any equipment we have available.

Certainly our provision for individual differences has been most inadequate. Our annual convoy type of education and our ability to manage attitudinal, social, and conceptual learning has been most uncertain and haphazard. To this point in time much of the programmed work appears to be taking place in elementary courses, remedial courses, etc.. It is the contention of the experimenter that the more able students are the ones who are most capable of benefiting from individualized self-paced instruction. Johnson (1969) says no plan has been described in which the student may advance at his own rate from assignment to assignment and achieve either early or delayed completion of his course. This is the goal toward the achievement of which audio tutorial teaching and other system approaches to instruction including this research are committed.

In traditional education too much emphasis has

been placed upon attempting to teach students in mass. There are those who still contend that universal higher education is incompatible with excellence. Nothing could be farther from the truth. Contemporarily, it is of prime importance that the emphasis be refocused upon teaching the individual student. The assumption that a society such as modern America's must make a choice between excellent education for a few people and a mediocre education for a large number is fallacious. If we liberate a student from the lockstep of our traditional courses and let him move forward at his own best pace and go on as far as he can and release teachers from much of the routine of exposition and drill and let them concentrate on enriching and smoothing the progress of individual students we will have improved learning.

The major task ahead is to learn how instructional devices can be most effectively incorporated in the educational process. To learn how to integrate the teacher, materials, program, and learners and most importantly to extend our knowledge in areas of learning other than informational acquisition and motor skill development.

Examples have been given that point out that if

a five year old child is moved to a foreign country and allowed to play freely for hours with no formal instruction at all he will learn the new language in a few months and will acquire the proper accent too. He is learning in a way that has significance and meaning for him and learning proceeds at an exceedingly rapid rate. Let someone try to instruct him in the new language basing the instruction on the elements which have meaning to the teacher and learning is tremendously slowed or even stopped. This illustration, a common one, is worth pondering. Why is it that left to his own devices the child learns rapidly in ways he will not soon forget and in a manner which has highly practical meaning for him, but all of this can be spoiled if he is taught in a way which involves only his intellect?

Experimental learning has a quality of personal involvement. It is self-initiated even when the impetus or stimulus comes from the outside. The sense of discovery, of reaching out, of grasping, of comprehending comes from within. It is pervasive as it is evaluated by the learner. Its essence is meaning. To give self-direction and freedom to students can clearly be a complete failure if it is simply a new method. Commitment and conviction are essential.



### Statement of the Problem

There are various reasons for attempting to individualize courses. Our society is committed to the significance of individual performance. A system of individualized instruction nurtures independent learning and as a result has the potential of producing individuals who are resourceful and self-appraising learners. Resourceful individuals of this kind cannot be produced in any significant numbers by our traditional educational environment in which the primary burden of initiating and maintaining learning is the job of the teacher rather than the learner. At the very least this should be a shared endeavor. Instruction which adapts to individual requirements seems impossible to envision without the inclusion of the notion of competence in the attainment of standards. Mastery of the material cannot be assured unless each has available the time and resources necessary.

Unfettered by the practical necessity for group pacing and for adjustments to a teaching strategy adapted to the group average, it appears possible for each student to attain a standard of performance that permits him to move on in confidence and knowledge. The possibility of any one individual gaining confidence

is enhanced by an environment in which he can progress to his requirements and purposes. Without the frustrations of moving ahead with the bright students or the discouragement of just keeping up with the less-bright students the individual has an improved chance for success. In this way a realistic sense of achievement is developed which encourages the use of one's abilities. It is time to pay something more than lip service to the differing abilities of individuals. Our educational system has an obligation to develop an operational capability in line with the facts of human behavior.

It appears that educational reform is largely oriented toward advances in individualizing education. The experiences indicate that certain fundamental requirements for individualization will have to be met if progress along these lines is to be realized. Conventional boundaries of grade levels and arbitrary time units for subject matter coverage must be redesigned to permit each student to work at his actual level of accomplishment in each subject to permit him to move ahead in the subject as soon as he masters the prerequisite for the next level of advancement. Well-defined sequences of performance objectives in the

subject areas must be established as guidelines in setting up a student's program of study. A student's achievement is defined by his position along this progression of advancement. A student's progress through a curriculum sequence must be monitored by adequate methods and instruments for evaluating his abilities and accomplishments for evaluating his abilities and accomplishments so that a teaching program can be adaptable to his requirements and readiness. Students must be provided with appropriate instructional materials in order to assure increasing competence in self-directed, self-paced learning. In order to accomplish this, teachers must provide the student with values of performance so that he can evaluate his own attainment. Teacher-directed learning must be replaced by teacher-guided, learner-directed accomplishment in order for the goals of individualized instruction to be achieved.

Central Oregon Community College agreed to allow a study to be made of these different methods of teaching college chemistry. Chemistry instructors for a number of years have been trying to find ways of making college chemistry more significant and relevant to the students who are non-chemistry majors but who require some

chemistry background. In addition community college teachers have also been concerned with making the courses available to everyone within the community who has a desire to know something about chemistry. Because a community college is primarily student oriented there is a need for a greater flexibility in the operation of the school and a correspondingly greater flexibility for the students. Unfortunately many of these people are employed or are homemakers or for some other reason cannot adjust their schedule to mesh with an arbitrary time schedule as prepared by the college. With a small school there is the added problem of conflicts when only one section of chemistry can be taught and one section of many other courses. This forces the student to make a decision that is irrevocable for a year. Again because of the small size there could be no trailer courses or summer school offerings in chemistry.

Individualization allows for students to begin and finish at any time without regard for the arbitrary time lock that is put on a traditional course. Greater flexibility, however, must not be achieved at the expense of learning. A programmed text approach and an individualized approach must not sacrifice the

student's achievement for the sake of ease of entering and finishing a program. The method of instruction must produce learning which is at least as effective as that produced by the traditional method of instruction.

## II. REVIEW OF RELATED LITERATURE AND RESEARCH

Szabo and Feldhusen (1970) studied the biology audio-tutorial system at Purdue University to determine those variables which have the most effect upon success in traditional type courses as compared to those with the most effect in a type of individualized instruction. In the 630 students studied it was found that intellectual predictors accounted for approximately 75 per cent of the variance, and the personality predictors accounted for less than 25 per cent. It appears that successful performance in an independent study biology laboratory system is correlated with verbal aptitude, achievement in mathematics and social studies, overall high school rank, and restraint, that is, the capacity to be serious minded and responsible.

In another paper by the same authors it was reported that mathematics reasoning skills and science achievements were significantly related to success in the audio-tutorial course. In the traditional course, verbal aptitude, mathematical computation skills, and restraint were significantly related to success. SAT verbal and the restraint scale were significantly related to the criteria in both types of courses. Mathematical

reasoning skills measured by CEEB mathematics and social studies were more often related to success in the audio-tutorial course, while prior achievements in mathematics occupational skills, that is, from mathematics grades, and science achievements from CEEB science were often related to success in the traditional course.

Weaver and Gibb (1964) have found that in science education there is very likely a significant relationship between self-confidence and achievement in those courses. This finding tends to confirm the feeling that many teachers have held for years that failure breeds failure while success breeds success. A teaching technique which eliminates the possibility of failure should therefore be reinforcing in a positive manner. Self-paced individual teaching achieves the ultimate in homogenous grouping with the advantages of not holding back the faster students and not embarrassing the slower students. In addition each student is challenged to his ability but not beyond. Chemistry teachers have observed for years the advantages of laboratory learning. Recent research indicates that students learn what they do and that learning is not a passive activity. Extending this concept from the laboratory

requires that each student be actively involved in the process of learning.

Flanders (1960) has pointed out that programmed instruction has always stressed that its particular educational advantage is the possibility of giving each student individual attention. Most linear programs seem designed and written from the viewpoint that the learners have no previous experience with the subject. Programers therefore have difficulty determining where to start and how much of any topic to include. The instructor is needed to determine and direct the individual needs for each student.

Melby (1963) has said that perhaps the most signal failure of American education is its failure to help students to see that they are in effect creating their own environment for growth, that they are engaged in their own education. There are growing signs of a return to a more human view of education and consequently a different role for the teacher. Goethe (1963) said, "When we treat a man as he is we make him worse than he is, when we treat him as if he already were what he could be we make him what he should be." Some teachers see differences among students as obstacles and yearn for a situation in which all of the students progress at



the same rate, complete the study of the material at the same time, receive passing marks on the same examinations, and are uniformly satisfied with their progress in the class. Others treat the differences as a challenge and adjust their own thinking and the class to attempt to meet these challenges.

Bugelski (1967) used nonsense syllables to find that each student seemed to be learning the task imposed on him in his own unique way and at his own rate. The students controlled their own learning and could take as long or as little time as desired. Each student continued so that he learned but each student learned in a different manner because of the different background that each had. The findings indicate two points. Adult learning is an automatic and chancy thing and it takes time for chance to happen. This should be taken into account in all teaching. Students are in a learning situation. They are learning all the time that mediators, words, or images are occurring. The trouble is that these internal events are not under the teacher's control or even the learners. The best the teacher can do is provide the stimulation and hope that the early learning of the student has provided a necessary and sufficient reservoir of cell assemblies. One can control the

learning process only by giving the learner adequate time for the appropriate assemblies to occur within his brain. If it is rushed, nothing much of value is going to happen. This is one of the prime virtues of the individualized self-paced approach to learning.

This does not mean that students should be turned loose without guides. As Taba (1962) has pointed out prolonged assimilations of facts without a corresponding restating of the conceptual schemes with which to organize them is bound to retard the maturation of thought. On the other hand, a premature leap into a more complex or a higher level of thought is likely to immobilize mental activity and cause a reversion to a lower level of thought. An appropriate transition from one level of thought to the other demands a proper match between the current level and that which is required. Determining the proper match is one of the most difficult tasks in teaching. In good teaching it is necessary for the teacher to respond and cause the student to think of the answer. The trouble is that the teacher side of the conversation cannot be as cognitively dealt with and carefully planned as Taba would like it to be. When the teacher is saying the right thing for some of the students he may very well be saying the wrong thing

for the rest of them. The individualized, self-paced, prearranged flexible sequences of give and take between teacher and students are exactly what programmed instruction tries to provide.

It is Gagne's (1965) contention that the major possibilities of predesigning instructional content to allow for individual differences have been exhibited not in the classroom or in the textbook but in programmed instruction. Browdy (1962) feels that there is less than is generally assumed that only a live teacher can provide. Any material that can be symbolized and that has some kind of logical and syntactical structure can be adapted for machine instruction. As to elicitation of a trial response, correction of trial response, practice of correct responses, inducement of an insight into relational patterns, and evaluation of any and all responses, there is little doubt that properly programmed machines will serve very adequately. These are their strong points.

Much has been made of the interest of teachers in grouping. It should be noted that only the most unfeeling teacher has ignored the individual student and many teachers make use of a variety of individualizing techniques.

The literature search did not reveal any research to compare the teaching of general college chemistry by the three methods of traditional text and lecture-discussion, programmed text and lecture-discussion, and programmed text and recorded lecture taken at individual rates. Consequently this study was designed to compare the three methods of teaching to determine if there is any significant difference in the learning that occurs between any of the three.

### III. THE EXPERIMENTAL DESIGN

This study involves the effectiveness of three different methods of teaching a one-year sequence of college chemistry to community college students.

#### Comparison Groups

The three groups studied were the students who enrolled in college chemistry in the fall of 1968, 1969, and 1971 at Central Oregon Community College. Because the study was concerned with the success of the student in a three term, 12 quarter hour sequence only those students who completed the year were included in the data for the traditional and programmed groups. The instructor had ten years of college teaching experience before the first group began and had a master's degree in chemistry.

The three groups can be characterized by the type of instruction they received into traditional, programmed, and self-paced individualized. Each included the entire population of students enrolling in the college chemistry course for the college. The students had no choice as to the type of instruction they received and each group represented a rather typical community college chemistry class.

The traditional class began in the fall of 1968 and included 30 students of whom 13 completed the sequence. The programmed class began in the fall of 1969 with 31 students and 13 completed the sequence. In the fall of 1971 48 students began the self-paced individualized course and five completed the sequence by the end of spring term 1972.

#### Description of Methods Used

The traditional course was taught with the typical three fifty-minute lectures and one scheduled three hour laboratory period per week. A typical college chemistry text was used. Lectures could be more properly described as lecture-discussion periods, as the students were encouraged to ask questions and there was a flexibility which allowed the class to pursue directions that were of interest to the group. The instructor maintained posted office hours but was available most of the day and encouraged students to drop in with chemistry problems at any time. An effort was made to know each student as soon as possible and individual differences were considered. It was necessary to maintain a schedule to cover the material that was deemed necessary for the course.

The laboratories were scheduled for three-hour blocks but the students were not required to leave at the end of the scheduled time. The only restriction was that no more than 20 could be in the laboratory at any one time because of safety considerations and the feeling that no more than that could be taught. The instructor was also the laboratory instructor and was able to use the time to work on an individual basis with the students. The laboratory experiments were ones selected and developed by the instructor to gradually develop the ability of the student to work independently. The experiments were quantitative from the beginning and required many measuring devices from automatic balances to burets. The third quarter was entirely devoted to instrumental analysis using, among others, such instruments as pH meter, Spectronic 20, Beckman DU spectrophotometer, refractometer, and polariscope. In the first quarter, Chemistry 201, the students had two tests, three quizzes, five laboratory experiments, and the final examination. The second quarter, Chemistry 202, there were three tests, seven quizzes, four laboratory experiments, and the final examination. In Chemistry 203 there were two tests, six laboratory experiments, and the final examination. All of the

above were instructor produced except the final examination which was the American Chemical Society Cooperative Examination in General Chemistry.

The programed course was taught with the three fifty-minute lectures and the three-hour scheduled laboratory per week. The prime difference was in the selected text. The text was a programed text, Chemical Principles by Runquist, Creswell and Head. This text was supplemented the last five weeks of the year by a short paperback covering descriptive chemistry. A schedule was posted for the students and they were encouraged to maintain the pace necessary to complete the material by the end of the third term. Many students found the pace too rapid for their ability. Lecture times were primarily spent answering questions and allowing the students to work on the text.

The laboratory operation was not changed although it was noted that there was an increased use of the textbooks in the laboratory. The author has, for a number of years, maintained a book cart in the laboratory for the use of the students. This cart is stocked with reference books, primarily general chemistry textbooks, which the students are encouraged to use in the laboratory and to check out. Fewer experiments were



completed in the laboratory to allow the students extra time to work in the programmed text.

In Chemistry 201 there were three tests, five quizzes, four laboratory experiments, and the final examination. In Chemistry 202 there were three tests, four experiments, and the final examination. In Chemistry 203 there were three tests, six experiments, and the final American Chemical Society examination.

The self-paced individualized course was taught using the same programmed text and descriptive text as in the programmed course. The self-paced instruction as conceived in this research attempts to incorporate the advantages of a programmed text with the advantages of individual contact with the instructor. In addition the scheduling problems are reduced by allowing the student to operate on his own schedule and not be tied to an arbitrary, administratively determined schedule. The instructor is available for explanation, reinforcement, and answering of questions anytime during the normal working day.

Lecture-discussion periods were held on a regular basis. These were recorded on cassette tapes and the normal "chalk board" work was put on transparencies as the lecture progressed. These transparencies were then

reproduced on ditto masters and copies were run for later use. The tapes and the dittoed notes were available within one hour at the library and in the instructor's office. Students had the option of attending the lecture or listening to the tapes at a time that fitted their schedule. A very limited number of students continued to attend the live lectures. Some had other classes scheduled at the same time, some were employed during the day, and many found that when they were behind the pace set by the instructor the lectures were not very beneficial. The most successful non-attending students were those who scheduled a regular time to listen to the tapes and who maintained that schedule. Chemistry 201 consisted of 13 tests and seven laboratory experiments plus the final examination. Chemistry 202 had eight tests, four experiments, and the final. Chemistry 203 had six tests, six experiments, and the American Chemical Society final.

The tests were available either from the departmental secretary or from the instructor. Students were free to work on the tests at any location they desired. The tests were graded within 24 hours and results were posted giving scores, the errors made, and a suggestion as to whether the student should proceed

or re-study and retake the test. As the year progressed the student was allowed to make his own decision regarding whether to go on or not. A student was allowed to repeat the test as many times as necessary to be successful and while all scores were recorded, only the last highest score was used for purposes of computing the final grade. For the tests the students had no time limit but they were encouraged to work as they would in a normal test situation. The final examinations each quarter were given using the strictest security measures. The results on the final examinations indicated that the students had learned the material. The final examinations had a time limit, were thoroughly proctored, and were used for an inordinate share of the final grade because they were the only tests that the instructor felt he had completely controlled. Students were allowed to have their test to facilitate studying for the final but required to turn them back in when they took the final. Students were not allowed to have access to their final examinations at any time.

Supplementary material was available to the students in the form of single-concept film loops which were always in the mathematics laboratory. These

covered areas such as slide rule, crystal structure, etc..

Laboratory instruction was conducted by reserving time for the course when the laboratory would be available and the instructor was on duty. The directions for each experiment were recorded on cassettes and players were available so the student could begin laboratory work at his convenience. As the year progressed the special instructions were decreased to zero so that the student with minimal instructions could begin, complete, and report the experiment. It was found that much of the individualized instruction occurred during the times that the laboratory was in operation and much interchange between students occurred during this time. The laboratory was open from nine to twelve hours per week. Most students found that they needed more than the minimal three hours to complete the experiments.

It should be emphasized that the students themselves had no choice as to the type of instruction they received. In many experiments the students do have some choice which introduces a selective process which can affect the data.

### Statement of Hypotheses

To facilitate analysis, the following questions relating to student achievement are presented in terms of null hypotheses:

1. There will be no statistically significant difference between the traditional, programed, and self-paced methods for the sequence Chemistry 201-203.
2. There will be no statistically significant difference between the programed and self-paced methods for the first quarter course Chemistry 201.

### Evaluation Instruments

The final examination for Chemistry 201 was instructor produced and was intended to thoroughly cover the material in the first quarter. The examination was given to those in the programed course and those in the self-paced course. It is reproduced in Appendix A. The final examination for the sequence taught by all three methods was the American Chemical Society Cooperative Chemistry Test in General Chemistry Form 1967. Norms on this examination are based on data from the

1967 National College Testing Program. The total group consisted of 3,295 students in 43 institutions completing a year's program of study. The means of the normative group for credit hours, hours of lecture per week, and hours of laboratory per week were in all cases higher than for those students at Central Oregon Community College. The test consisted of 60 items with a time limit of 105 minutes.

#### Statistical Treatment

As a result of looking at the high school and college grades for a large sample of students, schools, and colleges Bloom and Peters (1961) found a consistency in achievement patterns that is not generally recognized. Indeed their findings suggest that there is almost as much consistency between high school and college grades as there is among grades within a single institution. The correlation coefficients they found of .72 and .75 are close to the relationships of first and second term grades of about .80 within colleges. After 50 years of research and development the average correlation between scholastic aptitude tests and college achievement is of the order of .50, a figure that has not significantly changed from the correlation of .49 between

aptitude tests and college achievement as reported by Jordan in 1920. Thus in a half a century of research and development we have not materially improved our effectiveness in the prediction of academic achievement. Contrast this with a correlation of .75 reported between high school and college grades. In educational research in the past great use has been made of scholastic aptitude test scores for matching students in controlled and experimental populations, but it appears likely that grades may in the future become one of the important controls in educational experimentation. Because grades may also be used as an important criterion in determining the effectiveness of experimental procedures it was decided to use high school grade point averages as the control against which the experimental methods would be measured.

Multiple linear regression is a most direct and powerful approach to the effective formulation and resolution of a wide variety of research problems. The analysis of covariance is a technique that combines the features of analysis of variance and regression. Multiple regression analysis and multivariate correlation analysis have computational aspects which are similar but they are based on different assumptions. The assumptions

underlying the regression approach are less restrictive. For example, the predictor variable in linear regression models are not assumed to come from multivariate normal distributions. The analysis of covariance in this experiment is used to increase the precision of the randomized samples. The application uses the covariate, high school grade point averages, taken on each experimental unit before the treatments are applied, that predict to some degree the final response on the unit. Campbell and Stanley (1963) state that covariables such as prior grades may be used to provide an increase in power or significance at least as great as that with a pre-test. Analysis of covariance is therefore a statistical procedure which may be used when the research design includes a post-test but no pre-test.

The null hypotheses will be subjected to the F-test to determine if they can be rejected and if so to what degree of significance.



#### IV. DATA ANALYSIS

##### Presentation of Data

Table I presents the data obtained from the three groups in the experiment. High school grade point averages are given for all groups and American Chemical Society percentile scores are given for all students who completed the three term sequence in college chemistry. The 201 score is the result on the first quarter final examination for those programmed students who completed the entire sequence and for those self-paced students who completed the first quarter. The programmed and self-paced students used the same text and the same final examination for Chemistry 201. The Chemistry 201 final examination is reproduced in Appendix A.

TABLE I. HIGH SCHOOL GRADE POINT AVERAGES AND TEST SCORES

TRADITIONAL			PROGRAMED			SELF-PACED		
GPA	ACS		GPA	ACS	201	GPA	ACS	201
2.88	82		2.98	89	178	2.32		196
2.30	41		3.17	40	103	3.29		97
3.70	53		2.44	54	143	2.41		109
2.38	19		3.56	80	189	3.40	78	176
2.87	64		3.38	71	137	2.43		98
2.45	4		3.14	37	77	2.52		67
3.10	78		2.50	52	141	3.91	90	175
2.89	41		3.00	3	33	2.08		83
3.05	81		2.65	89	116	2.45	75	167
3.60	56		2.82	30	70	3.46		193
2.80	49		1.89	64	92	3.62		206
2.66	30		3.00	75	114	2.25	92	198
2.70	56		3.21	75	105	2.64	92	158
Total	37.38	654	37.74	759	1498	36.78	427	1923
Mean	2.88	50	2.90	58	115	2.83	85	148

### Interpretation of Data

The data were analyzed by the method of covariance as described by Snedecor and Cochran (1967) and the F values were then compared to determine at what level of confidence the null hypothesis could be rejected.

H1: There will be no statistically significant difference between the traditional, programmed, and self-paced methods for the sequence Chemistry 201-203.

The test for the hypothesis yielded an F value of 4.14 which exceeded the 3.35 one would expect for 95 per cent reliability. The null hypothesis can therefore be rejected and it can be stated that there is a difference in learning that occurred among the three procedures.

A comparison of the means as shown in Table I indicates that the programmed procedure produces slightly better results than the traditional. The self-paced individualized method produces much better results than either the traditional or programmed procedures.

H2: There will be no statistically significant difference between the programmed and self-paced methods for the first quarter course Chemistry 201.

The test for this hypothesis yielded an F of 2.96 which exceeded the 2.94 value at 90 per cent reliability. Although this is not as significant as the other tests, it has sufficiently high reliability to reject the null hypothesis. There is, therefore, a difference in the learning achieved in one quarter between the programmed and self-paced.

The above reported F values were calculated using the following equation:

$$F = \frac{n_t - a - 1}{a - 1} \left[ \frac{\left( \Sigma y_t^2 - \frac{\Sigma (y_t)^2}{n_t} - \frac{\left( \Sigma x_t y_t - \frac{\Sigma x_t \Sigma y_t}{n_t} \right)^2}{\Sigma x_t^2 - \frac{\Sigma (x_t)^2}{n_t}} \right)}{\left( \Sigma y_t^2 - \frac{\Sigma (y_1)^2}{n_1} - \frac{\Sigma (y_2)^2}{n_2} - \frac{\left( \Sigma x_t y_t - \frac{\Sigma x_1 y_1}{n_1} - \frac{\Sigma x_2 y_2}{n_2} \right)^2}{\Sigma x_t^2 - \frac{\Sigma (x_1)^2}{n_1} - \frac{\Sigma (x_2)^2}{n_2}} \right)} \right] - 1$$

where:

- $F$  is the inverted beta distribution,
- $n_t$  is the total number of students from the two populations,
- $a$  is the number of treatments,
- $x_t$  are the high school grade point averages for all of the students,
- $x_1$  are the high school grade point averages for the students in the first named method of teaching,
- $x_2$  are the high school grade point averages for the students in the second named method of teaching,
- $y_t$  are the final examination scores for all of the students,
- $y_1$  are the final examination scores for the students in the first named method of teaching,
- $y_2$  are the final examination scores for the students in the second named method of teaching,
- $n_1$  is the number of students receiving the first named method of teaching, and
- $n_2$  is the number of students receiving the second named method of teaching.

The  $F$  values for comparison were obtained from the tables of Snedecor and Cochran.

## V. RESULTS OF THE EXPERIMENT

The purpose of the experiment was to determine the effect of innovative teaching techniques on the learning in a community college chemistry class. An additional part of the experiment was to produce solutions for some of the problems community college chemistry teachers in a small college must attempt to solve.

While the experiment indicated that there was no change in learning when a programmed approach was substituted for the traditional method, there was a significant increase in learning when a self-paced individualized approach was used.

### Conclusions

The self-paced approach worked well in allowing for individual differences in rates of learning. The rates of learning differences could be caused by different backgrounds, different motivational levels, different "outside" pressures such as jobs or loads, or different reaction to a non-pressured atmosphere. The rate of learning of each student appears to vary as other classes require more time, as motivation changes, and as their

mood changes. Some students work in spurts of achievement followed by periods of relative inactivity while others found it to their advantage to maintain their achievement at a rather consistent level. Some students found it necessary to spend more than 50 minutes listening to a 50 minute tape because they relistened to many parts until they were sure they understood what was being taught. The students were allowed to determine when they were ready for an examination and many found a level of inertia that was too great to overcome. It is quite understandable that a student might tend to "over-study" even though there was no penalty for failing an examination. With some students self-pace became zero-pace. This seemed to occur after the student felt he was behind the pace he should be maintaining. Because there was no pressure being exerted in chemistry, it was usually the last assignment attempted. If all courses were being taught by the self-paced method, this problem could be eliminated.

Scheduling difficulties were largely eliminated. In a small community college where only one section of chemistry can be offered, it is a very real advantage to the student to not be restricted to one time. Again

because of size restrictions, chemistry could not be started at any quarter other than fall. A student wishing to begin winter quarter had to wait until the following fall. Although it would not be normally advised, a student has the option of completing the three quarter sequence in less than three quarters as illustrated by the student who started in January and completed the entire sequence in June. With some slight modifications in the business and registrar's offices, students could begin at any time. This causes a great increase in opportunity for education.

There was more active involvement of the student in the business of learning and it is felt that this contributed to the increased learning as compared to the more passive student attitude in the traditional approach. The more active the role of a student then, the more learning will occur. Any procedure that increases the involvement of the student will likely result in increased learning. The self-paced approach attempted to increase the self-instruction while retaining the teacher directed thrust of the subject matter. It is especially essential in self-paced instruction to have very carefully determined performance criteria. There was an increased amount of peer



instruction but it was not determined whether this was due to a lack of competition for grades or the feeling that they were all faced with the same problem of learning. It is also very likely that as active involvement with their own learning increased they became more actively involved with the learning of their peers.

The students were informed at the beginning of the course that there was no possibility of failure. The most negative result was that they might not finish and would therefore not receive a grade. There were a rather large number of average students who did not complete the first course in the sequence. This is probably a reflection of the inability of many community college students to use self discipline.

Among administrators and fellow faculty members there was a feeling of general uneasiness to outright antagonism toward the self-paced method. Some of the expressions of this feeling ranged from "jokes" about having no classes to teach, concern that their advisees were not getting through, to a statement by the experimenters immediate supervisor that he could not evaluate the experimenter for promotion because there were no scheduled classes.

There were additional disadvantages to the self-paced method. Instructors do many things in lecture to make the subject more interesting and without these visual clues some students found the tapes boring. The completion rate for the sequence was considerably lower than with the traditional approach. While some of this can be attributed to the increased number who were afforded the opportunity to begin the sequence, the number who completed the sequence was so low as to cause considerable concern. The instructor must be available to the students on a non-scheduled drop-in basis. If more than one instructor were involved this would greatly simplify the problem. The instructor must be sufficiently experienced to teach any part of the course at any moment. There is not time to prepare a lecture when the students are all at different locations and studying different material. The grading load at times became intolerable. This was due to the volume of tests, the need for rapid return, and the inefficiency of grading only a few tests over the same material at a time.

It should be noted that although the experimenter is convinced of the improved learning by the self-paced method he will offer a traditional course in the future.

### Recommendations for Further Study

While the experiment answered some very important questions, there are some others that could be the object of additional work.

1. What is the optimum and maximum number of students using the individualized self-paced study method?
2. What areas of the self-paced instruction could be effectively handled by paraprofessionals, and how much could this increase the usefulness of the professional?
3. Does the self-paced approach produce students with a higher retention ability and a higher chance of success in the next higher chemistry course?
4. Does the self-paced approach do a better job of producing educable persons who are resourceful and self-appraising learners? In short does it produce better citizens?
5. What is the attitude of the self-paced students toward chemistry and science after the sequence?
6. What students can make the best use of the self-

paced approach? Is the self-paced approach best for all levels of students or is it only best for the average? Is there a correlation with personality which could be determined in time to do a more effective job of advising?

7. Would modifying the self-paced approach to attempt to increase the number of students completing the sequence destroy all of the advantages? In other words could deadlines be applied to keep the students progressing without significantly decreasing the learning?

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## APPENDIX



## Final Examination Chemistry 201

General Directions: For all problems show the set-up and express all answers to the correct number of significant figures.

1. Use slide rule to do the following calculations:

$$\log 2.85 = \underline{\hspace{2cm}} \qquad \text{antilog } 2.85 = \underline{\hspace{2cm}}$$

$$\log 1.68 \times 10^{-6} = \underline{\hspace{2cm}} \qquad \text{antilog } -3.41 = \underline{\hspace{2cm}}$$

$$\sqrt[4]{2143} = \underline{\hspace{2cm}} \qquad \sqrt[3]{11.63} = \underline{\hspace{2cm}}$$

(hint use logs)

$$3.69^3 = \underline{\hspace{2cm}} \qquad 24.8^2 = \underline{\hspace{2cm}}$$

$$\sqrt{46.3} = \underline{\hspace{2cm}} \qquad \sqrt[3]{184.3} = \underline{\hspace{2cm}}$$

2. Compare and contrast the size and stability of Cs and  $\text{Cs}^+$ . Explain your answer.

3. Arrange in order of increasing size O, S, Se. Explain your answer.

4. Arrange in order of increasing size Xe,  $\text{I}^-$ ,  $\text{Cs}^+$ ,  $\text{Ba}^{++}$ . Explain your answer.

5. Analysis of a compound shows 0.83% H, 45.8% Mn, and 53.4% O. Calculate the empirical formula.
  
6. Gold crystallizes in the face-centered cubic arrangement. The observed unit cell length is 4.070 Å. If you can assume that gold consists of hard spherical atoms in contact, what radius would you need to assign to a gold atom in the solid state?
  
7. Suppose you have a mixed hexagonal close-packed arrangement where the interior atoms are type A, the corner atoms are type B, and atoms in the middle of the top and bottom faces are type C. What is the simplest formula?
  
8. You have a face-centered cubic arrangement of atoms in which the corner atoms are type A and those at face-centers are type B. What is the simplest formula of the compound?

9. Sodium metal crystalizes in the body-centered cubic arrangement. If the unit cell edge is  $4.24 \text{ \AA}$ , what would be the calculated density of the sodium?
10. How many grams of acetic acid ( $\text{HC}_2\text{H}_3\text{O}_2$ ) are required to make 4.00 liters of 6M solution?
11. Write equations for the following reactions.
- a. emission of a beta particle from lead 214.
  - b. emission of an alpha particle from radon 220.
  - c. bombardment of cobalt 58 with a neutron followed by alpha emission.
12. Draw electron dot structures for each of the following.
- ammonium ion                      bromine molecule

propene  $C_3H_6$ aluminum phosphate  $AlPO_4$ 

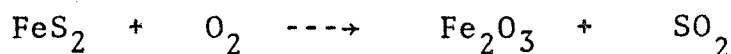
13. Calculate the following:

$$pH=9.23; \{^aH_3O^+\} = \underline{\hspace{2cm}} \quad pH=2.86; \{^aH_3O^+\} = \underline{\hspace{2cm}}$$

$$pH = \underline{\hspace{2cm}} \quad \{^aH_3O^+\} = 3.62 \times 10^{-8} M$$

14. 49.0 grams of pure  $H_2SO_4$  are added to water to make 51.9 ml of a solution of 1.52 g/ml density. Calculate the concentration of the solution in percent, molarity, and molality.

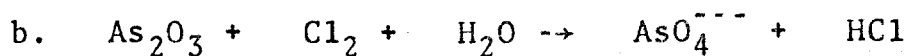
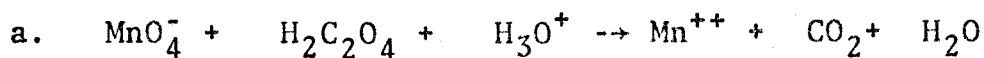
The following four questions are based on this equation.



15. How many moles of iron III oxide will be produced by the reaction of 6.24 moles of oxygen with an excess of iron pyrite?

16. What volume of oxygen (STP) will react with 3.85 moles of iron pyrite?
  
  
  
  
  
  
  
  
  
  
17. How many grams of iron pyrite will need to react to produce 48.9 grams of sulfur dioxide?
  
  
  
  
  
  
  
  
  
  
18. 100.0 grams of iron pyrite is mixed with 100.0 grams of oxygen and allowed to react until one of the reagents is exhausted. Determine the limiting reagent and calculate the number of moles of iron III oxide produced.

19. Balance the following equations by the redox method.



20. Give the formula of the ion or symbol of the element of lowest atomic number which has:

minus 2 charge and 12 filled p orbitals \_\_\_\_\_

plus 2 charge and 10 filled d orbitals \_\_\_\_\_

plus 2 charge and a filled orbital in the sixth quantum level \_\_\_\_\_

eight filled p orbitals \_\_\_\_\_

an orbital with principle QN of 7 \_\_\_\_\_

seven occupied d orbitals \_\_\_\_\_