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EFFECTS OF SECONDARY SCHOOL DISCOVERY LEARNING EXPERIENCES ON PERFORMANCE IN COLLEGE CHEMISTRY

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EFFECTS OF SECONDARY SCHOOL DISCOVERY
LEARNING EXPERIENCES ON PERFORMANCE
IN COLLEGE CHEMISTRY

by

Donald Ray Wilson, Sr.

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF SECONDARY EDUCATION

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Donald Ray Wilson, Sr.

entitled EFFECTS OF SECONDARY SCHOOL DISCOVERY LEARNING EXPERIENCES ON PERFORMANCE IN COLLEGE CHEMISTRY

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of DOCTOR OF PHILOSOPHY.

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Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Robert J. Letson
Dissertation Director

Date 4/23/82

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SIGNED: Donald R. Wilson

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ABSTRACT

The purpose of this study was to assess the extent of discovery learning opportunities in Arizona secondary chemistry classrooms and to determine their relationship to performance in selected areas of freshman college chemistry at the University of Arizona.

For the purpose of this study two questionnaires were developed, one to gather data relating to students' participation in discovery learning activities in high school chemistry and the other to assess their use of learning resources at the University of Arizona.

Interviews were conducted with 15 volunteers from the subjects of this study. The information provided by these volunteers concerning their high school chemistry background was consistent with information obtained from the questionnaires.

Examination and laboratory scores were obtained from the records of the chemistry department, to assess student performance in lecture and laboratory.

The students' responses on the Learning Activities Questionnaire were used to form a discovery index score, which was correlated with college chemistry examination scores, college laboratory scores, and student-reported use of learning resources.

The lack of relationship between the discovery index scores and college chemistry examination scores was indicated by a partial correlation of -.10 which was not statistically significant at the .05 level.

A statistically significant partial correlation of .20 indicated the discovery index scores were related to college laboratory scores.

No significant relationship was found between discovery index scores and students' use of learning resources at the University as indicated by the Pearson correlation of .15, which was not significant at the .05 level.

CHAPTER 1

STATEMENT OF PROBLEM

Introduction

Science education was an area of intensive investigation during the decade of the sixties, a decade of change not only in content and organization of secondary school science, but also in renewed study of learning theory.

One of the largest single influences on learning theory has been Jerome Bruner's book, The Process of Education (1960), which reported on a science education conference held at Woods Hole, Massachusetts, under the auspices of the National Academy of Sciences (Shulman and Tamir 1973). One major area of discussion in this book is conceptions of the teaching-learning process. The focus of this discussion is on processes by which learning occurs. The processes discussed by Bruner, known as "discovery learning", are characterized by increased student participation in the learning process. Bruner defined discovery as "all forms of obtaining information for oneself through the use of one's mind" (Bruner 1961, p. 22).

Curriculum reforms of the sixties in the area of science education were influenced to a large extent by the ideas set forth in The Process of Education. As these ideas were translated from concepts to a practice, a period of intensive research followed in which traditional students were compared to the students of the new curricula in a variety of experiments which often produced disappointing results. In most studies little or no difference was detected between new and old curricula, and the studies that produced significant differences one time failed to do so in replication (Shulman and Tamir 1973).

The lack of experimental evidence for the support of discovery learning not only indicates a lack of knowledge of what is the best instructional strategy, but also may indicate possible flaws in what is an accurate description of the way students learn. The mixture of results may not be a reflection of the differences in students who have participated in discovery learning activities, but could be indicative of research design problems. Some design problems were: the outcome measures selected were inappropriate to assess the differences, the experimental treatment was not sufficiently different from that of the comparison group, or measurements were taken too soon after treatment to detect long term effects of learning experiences (Berlanger 1969).

Statement of the Problem

The purpose of this study was to assess the extent of discovery learning opportunities in Arizona secondary chemistry classrooms and to determine their relationship to performance in freshman chemistry at the University of Arizona.

Areas of performance in college freshman chemistry that were investigated included:

1. Students' performance in lecture-recitation.
2. Students' performance in laboratory.
3. Students' use of learning resources in college freshman chemistry.

The following questions provided direction to the study:

1. To what extent are students afforded the opportunity to participate in discovery learning activities in Arizona secondary classrooms?
2. What is the relationship between participation in discovery learning activities in secondary chemistry and performance in lecture-recitation section of college freshman chemistry?
3. What is the relationship between participation in discovery learning activities in secondary chemistry and laboratory performance in college freshman chemistry?
4. What is the relationship between participation in discovery learning activities in secondary chemistry and student use of learning resources in college freshman chemistry?

Rationale of the Study

In an analysis of the curricular reforms of the decade of the sixties, Wittrock stated, "So far as these curricular demonstrations are concerned, learning by discovery is still a hypothesis--an untested one at that" (Wittrock 1966, p. 39).

In writing of discovery learning, Bruner (1961, p. 25) stated:

> Practice in discovering for oneself teaches one to acquire information in a way that makes that information more readily viable in problem solving. So goes the hypothesis. It is still in need of testing. But it is an hypothesis of such important human implications that we cannot afford not to test it--and testing will have to be in the schools.

In the same article, he hypothesized the following three advantages to discovery learning:

1. One learns the heuristics of discovery.
2. One increases his retention of material.
3. One experiences increased self reliance and intrinsic motivation as a result of participation in discovery learning.

This is the perspective from which this study investigated discovery learning. Discovery learning experiences were viewed as learning experiences which occur in chemistry classrooms with varying frequency. The extent of a student's participation in discovery learning, compared with selected variables indicative of performance in college freshman chemistry, served to assess the effects of discovery learning.

Statistical Hypotheses

1. There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in lecture-recitation portion of freshman college chemistry.

2. There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in freshman college chemistry laboratory.
3. There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their use of learning resources of freshman college chemistry.

Setting of the Study

This investigation concerned itself with Arizona high school students enrolled in freshman chemistry at the University of Arizona. These students had not had any prior experience in a college science class and had graduated from high school within the last three years. They all attended the lecture sections of a single instructor.

Scope and Limitations

Although a student participates in many learning activities during his tenure in secondary school, those of his secondary school chemistry class in particular should have discernible effect on his performance in freshman chemistry. This study was designed to measure the extent of discovery learning opportunities and to determine their relationship to performance in selected areas of freshman chemistry.

1. The subjects consisted of 171 college freshmen students who were enrolled in freshman chemistry for the first time at

the University of Arizona and had studied chemistry at an Arizona secondary school.

2. Subjects were selected from college freshmen chemistry classes that were taught by the same instructor.
3. All participants were volunteers.
4. Data were gathered during the fall semester, 1981.

Assumptions of the Study

1. A student's performance in freshman chemistry is in someway related to his prior learning experience in secondary school chemistry.
2. A student can recall learning activities from secondary school chemistry with sufficient accuracy to report the extent of their occurrence on a questionnaire.
3. Learning activities may be classified as either those which promote discovery learning or those which do not promote discovery learning.

Definition of Terms

Discovery Learning - A process which occurs inside the learner as the learner uses his cognitive abilities to reorganize previously acquired information into a new structure that permits understanding of the problem that produced the need for a new structure. Implicit to the above defintion is a situation in which the learner encounters a task to perform without any readily apparent means of performance, where there is contradiction of existing information, or when he is asked to educe symmetry or structure from a situation in which none seems to exist.

Learning Activity - Stimuli which are a part of an instructional program, presented to the learner with the intent of producing a change in behavior.

Lecture Recitation Section of Freshman Chemistry - That portion of freshman chemistry in which the students attend lecture, solve problem assignments and take exams.

Laboratory Section of Freshman Chemistry - That portion of freshman chemistry in which students perform experiments and report results. Students register for laboratory independent of lecture recitation sections.

Learning Resources in Freshman Chemistry - Resources available to students outside the laboratory-lecture portion of the course. These include computer-aided instruction, tutorial services provided by the department, instructor-conducted review sessions, as well as student-selected activities, such as private study groups and printed material other than text and laboratory manual.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The purpose of this chapter is to review the literature related to discovery learning as it pertains to instruction in high school chemistry. The literature to be reviewed is divided into six parts: the first is the psychological basis for learning. The second part reviews the literature of modern learning theorists and educational psychologists concerning discovery learning. The third part of this review examines the literature discussing the structure and nature of science and the implications this has for curricular decisions. The fourth section discusses discovery learning while the fifth reviews research conducted in science discovery learning in high school chemistry. The sixth section reviews selected literature pertinent to the research methodology of this study.

Psychological Basis for Learning

In discussing roles of teaching theories in the development of educational practice, Broudy (1963, p. 1) stated:

> What sort of teaching theory will command interest during a given period of history depends on what sort of learning carry a premium in that period. In a period when science and mathematics are richly rewarded, educational theorists strain to formulate new methods for teaching these subjects...

International affairs affecting the United States in the 1950's inspired a renewed interest in competence, proficiency, power and excellence in education in general and in particular in the natural and technical sciences (Mason 1972).

As this concern for improvement of education gave rise to projects to improve science curricula, the aid of many scholars was enlisted. Among these scholars were psychologists whose views of the nature of learning became influential in the development of the new science curricula.

The most prominent families of contemporary learning theory are those of the behaviorist family and the Gestalt-field family of cognitive field theories. Although both families use the results of scientific experimentation to form their theories of learning, there is a wide divergence given to the interpretation of the results of the experiments (Bigge 1976). This difference in interpretation of experimental results provides very different views of what constitutes sound educational practice.

The behavioristic family of psychology has as its modern proponents B.F. Skinner and Kenneth W. Spence. These psychologists are sometimes termed neo-behaviorists, to distinguish their positions from that of the earlier behaviorists who placed more emphasis on the physiological aspects of behavior (Bigge 1976).

The neo-behaviorist can be characterized by several common fundamental tenets, the first being the proposal that psychology be based on objective scientific observation. Spence (1960, p. 79) stated:

> As scientists we are interested in discovering and formulating a body of knowledge concerning the behavior of living organisms that is continuous with and has the same properties, empirical and logical, as the knowledge sought in the other natural sciences. Since the attainment of such knowledge requires methods of observation that assure publicly verifiable concepts, we have naturally insisted on such techniques.

The second proposition is the neutrality of the learner. Skinner (1953, p. 23) suggested:

> We are concerned, then with the causes of human behavior. We want to know why men behave as they do. Any condition or event that can be shown to have effect on behavior must be taken into account. By discovering and analyzing these causes, we can manipulate them, we can control behavior.

Skinner (1971, pp. 44-45), in an address to the Western Symposium on Learning, attributed current problems in education to the lack of recognition of the neutrality of the learner, saying:

> We have been to ready to assume the student a free agent, that he wants to learn, that he knows best what he should learn, that his attitudes and tastes should determine what he learns, and that he should discover things for himself rather than learn what others have already discovered. These principles are all wrong and they are responsible for much of our current trouble.

The neo-behaviorists also insist that man is in many ways similar to lower animals and that results of animal experiments can be extended to human learning. According to Skinner (1971, p. 37), "The fact that much of the early work involved the behavior of lower animals such as rats and pigeons has often been held against it. But man is an animal, although an extraordinarily complex one, and shares many basic behavioral processes with other species."

The neo-behaviorist also advocates the use of operant conditioning, used to shape animal behavior, as a means of instruction.

The only change is the change in contingencies. In comparing learning in pigeons and human learning, Skinner (1971, p. 39) stated:

> We do not say that about a pigeon; we only say that under the conditions we have arranged, a pigeon learns. We should say the same thing about human students. Given the right conditions men will learn--not because they want to, but because, as the result of genetic endowment of the species, contingencies bring about changes in behavior.

Skinner (1971, p. 43) envisions progress in the application of stimulus-response psychology to education and so stated in his address to the Western Symposium on Learning:

> Current applications of operant conditioning to education are no doubt crude, but they are beginning, and a beginning must be made... But we are on the verge of a new educational 'method'--a new pedagogy--in which the teacher will emerge as a skilled behavioral engineer. He will be able to analyze the contingencies which arise in his classes, and design and set up improved versions. He will know what is to be done and will have the satisfaction of knowing that he has done it.

Although education may not produce "behavioral engineers," one cannot deny the influence of the neo-behaviorist on educational practice.

The other school of psychology which has strongly influenced contemporary education practice is Gestalt or field psychology. Max Weltheimer, the German philosopher-psychologist was first to state the position of Gestalt psychology, and two of his colleagues, Wolfgan Kohler and Kurt Koffla, were primarily responsible for publicizing it in the United States (Bigge 1976).

Kurt Lewin took the spirit of Gestalt psychology, added some new concepts, applied some terms from geometry and mechanics and called it field psychology, also referred to as topological and vector psychology (Thrope and Schmuller 1954).

Gestalt-field psychologists agree with the behaviorists that psychology should be based on careful observation. An important difference is the way the observations are analyzed. Behaviorists insist on objective and descriptive analysis of data, while the Gestalt-field psychologists makes use of constructs to interpret observations. Lewin (1951, p. 219) maintained:

> Topological and Vectoral concepts combine power of analysis, conceptual precision, usefulness for derivation and fitness for the total range of psychological problems in a way which, in my opinion, is superior to any other known conceptual tool in psychology.

Lewin's statement is a contrast to Skinner's (1938, p. 44) delineation of systematic descriptive behaviorism: "It confines itself to description rather than explanation. Its concepts are defined in terms of immediate observations and are not given local or physiological properties."

The Gestalt-field psychologists do not discuss behavior outside of the context in which it occurs. The holistic view maintains that the whole is greater than the sum of its parts (Thorpe and Schmuller 1954).

Lewin (1951, p. 62) expresses the holistic idea this way:

> Many psychologists, particularly those who followed the theory of conditioned reflex, have confused this requirement for operational defintions with a demand for eliminating psychological descriptions. They insisted on defining 'stimuli' superficially in terms of physics ... to describe a situation objectively in psychology actually means to describe the situation as a totality of those facts and of only those facts which make up the field of the individual. To substitute for that world ... the world of anybody else is to be not objective, but wrong.

This holistic view of psychology suggests that the acquisition of facts outside of contextual background is uneconomical learning. Bruner (1960, pp. 32-33) stated:

> Teaching specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical in several deep senses...an unconnected set of facts has a pitiably short half life in memory. Organizing facts in terms of principles and ideas from which they may be inferred is the only known way of reducing the quick rate of loss of human memory.

The Gestalt-field psychologist recognized the need for the learning of facts but only in the context of the whole. The reduction of concepts to a series of facts to be presented atomistically may not be meaningful to the student and result in short term gains (Thorpe and Schmuller 1954).

Combs (1962, p. 60) in discussing the effect of personal meaning, stated:

> ... As any teacher is aware, mere exposure to an event is not a guarantee that the event will be perceived by the individual or be available on latter occasions. Something more than confrontation with events is necessary to insure inclusions of perceptions in the field and their availability on later occasions. This availability seems dependent upon at least two factors: (a) the individual's discovery of personal meaning, and (b) the satisfaction of need.

The field psychologist is also concerned with the motivation of the student to learn. Bruner (1960, p. 72) commented on this, saying:

> Short-run arousal of interest is not the same as long-term establishment of interest in the broadest sense. Films, audio-visual aids, and such other devices may have a short-run effect on catching attention. In the long run, they may produce a passive person waiting for some curtain to go up to arouse him.

This concern for motivation and personal meaning in learning is also expressed in the concern for the surroundings in which learning takes place. This view was expressed in Perceiving, Behaving, Becoming: A New Focus for Education (Combs 1962, p. 93) in the following statement:

> The people around the individual form the climate and the soil in which the self grows. If the soil is fertile and the climate wholesome, there is vigorous and healthy growth.
>
> If the climate is unwholesome and unkind, growth is stunted or stopped, and illness occurs. There is either growth or non-growth ... knowledge then is distorted or closed out and growth is stopped. Learning under these circumstances is in terms of self protection, not in terms of self growth.

An interaction of the learner with his surroundings is expressed in this statement as well as the mediation of stimulus from the environment.

This brief review on the two major contemporary schools of psychology contrasted the views of each. In the next section, literature is reviewed which describes how these views are used to form descriptions of learning which are then used to construct curricula.

Learning Theory

Learning theories are systematic descriptions of the nature of learning. Three important questions for which these systematic views of learning seek answers are: 1. What is the essential process called learning? 2. How is learning transferred from one situation to another? 3. What should be emphasized in teaching (Bigge 1976)?

Contemporary learning theories are influenced greatly by psychology. Thorpe and Schmuller (1954, p. 5) stated:

> Psychology--from which most learning theories derive their substance--investigates the 'mental' aspects of life as manifested in behavior. Education must direct whatever 'know-how' concerning learning it has at its command to the attainment of the purposes for which it (education) was established.

Bigge (1976, p. 4) described the influence of psychology on educational practice as he stated:

> When teaching moved from the mother's knee to a formalized environment designed to promote learning it was inescapable that a small group of persons would arise to begin speculating about whether schools were getting the best possible results. Then, professional psychologists and educators who critically analyzed school practices found that development of more or less systematic schools of thought in psychology offered a handy tool for crystallization of their thinking. Each of these schools of thought has contained, explicitly or implicitly, a theory of learning. In turn, a given theory of learning has implied a set of classroom practices.

To the behaviorist, learning is a change in behavior elicited by the reaction of the learner to stimuli which are reinforced. Skinner (1968, p. 10) says:

> Extremely complex performances may be reached through successive stages in the shaping process, the contingencies of reinforcement being changed progressively in the direction of the required behavior. The results are quite dramatic. In such a demonstration one can see learning take place. A significant change in behavior is often obvious as a result of a single reinforcement.

Skinner viewed the question of transfer as a problem of making behavior contingent on circumstances in the environment outside the classroom. He expressed this view (1968, p. 86) in saying:

> ... the real issue is whether the teacher prepares the student for the natural reinforcers which are to replace contrived reinforcers used in teaching. The behavior which is expedited in the teaching process would be useless if it were not to be effective in the world at large in absence of instructional contingencies.

The behaviorists proposed that instruction may best be planned by answering the following questions (Skinner 1968, p. 19):

> What behavior is to be set up? What reinforcers are at hand? What responses are available in embarking upon a program of progressive approximations which lead to the final form of behavior? How can reinforcements be most efficiently scheduled to maintain behavior in strength?

Skinner (1968, p. 22) went on to point out that this requires new methods of presenting materials, "We have every reason to expect, therefore, that the most effective control of human learning will require instrumental aid. The simple fact is that, as a mere reinforcing mechanic, the teacher is out of date."

The Gestalt-field psychologist proposes a different view of learning. To Brunner (1960) the act of learning had three almost simultaneous processes:

1. Acquisition of new information.
2. Transformation, the process of manipulating knowledge to make it fit a new task.
3. Evaluation, checking whether the way we have manipulated the information is adequate to the task. In the learning of subject matter there is usually a series of episodes, each episode involving the three processes.

Bruner maintained that for transfer of training to be possible the student must have an understanding of the fundamental principles and ideas (Bruner 1960). The path to this understanding is through 'optimal structure'. Bruner pointed this out in stating, "... here it suffices to say that such merit of a structure depends on its power for simplifying information, for generating new positions, and for increasing the manipulability of a body of knowledge" (Bruner 1966, p. 41).

In discussing what constitutes the best means of instructing, Bruner identified predisposition of the student, structure of the discipline, and sequence of materials and reinforcement as central to planning effective instruction (Bruner 1966).

Bruner (1966, p. 72) went on to state, "... to instruct someone in these disciplines is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge... knowing is a process, not a product."

Not all learning theorists are as affected by a single model of psychology. Gagné's theory of learning was an example of an eclectic psychological approach to the formulation of a systematic description of learning. He noted (1970, p. 20) the need for an eclectic psychological basis for learning by stating:

> Thorndike wanted to study animal association. Parker was studying animal reflexes. Ebbinghaus studied the memorization of verbal lists. Kohler was studying the solving of problems by animals. By some peculiar semantic process, these examples became prototypes of learning, and thus were considered to represent the domain of learning as a whole, or at least in large part. Somehow, they came to be placed in opposition to

> each other: either learning was all insight or all learning was conditioned response. Such controversies have continued for years and have been relatively unproductive in advancing our understanding of learning.

Gagné's view was that there are eight different types of learning, beginning with simple signal learning, that is, responding to a signal, ending with the complex phenomena of problem solving. He proposed that rather than concentrating on the act of learning, we study conditions under which that type of learning occurs.

One of his conditions was that the learner have the prerequisite learning experiences to gain from the planned activity. Gagné viewed the types of learning as hierarchical in nature, with mastery of each necessary before being able to master the next (Gagné 1970).

Gagné's conditions of learning were often associated with performance or competency-based education and the mechanistic instructional technology used to plan this type of instruction (Bigge 1976).

Although contemporary teachers may have not studied learning theory as such, most have studied the psychologies which are the basis for these theories. Bigge suggests that most educators hold an eclectic position and, therefore, use the learning theories of both major psychologies to plan instruction (Bigge 1976).

Structure of Science

Another important influence on science teaching came from a movement known as the structure of disciplines movement. "A central notion in this theory was that teaching should stress the underlying concepts and processes of each field of scholarly inquiry such as mathematics, language, physics, chemistry, biology or history" (Mason 1972, p. 136).

The structure of disciplines movement had as its main proponents Jerome Bruner and Joseph Schwab. Bruner wrote of the structure of knowledge, and Schwab writes of the nature of science and inquiry; both related these writings to science teaching (Mason 1972).

Schwab (1964, p. 13) described the relationship of structure of a discipline to teaching in stating, "... for to know what structure underlies a given body of knowledge is to know what problems we shall face in imparting this knowledge." Bruner (1960, p. 20) saw structure as central to teaching so that students gain usable knowledge and stated:

> Just as the physicist has certain attitudes about the ultimate orderliness of nature and conviction that order can be discovered, so a young physics student needs some working version of these attitudes if he is to organize what he learns as useable and meaningful in his thinking.

Both of these writers saw that knowledge was rapidly changing and that only through understanding the structure could students be prepared to face these changes. Schwab (1964, pp. 29-30) contended that:

> The revisonary character of knowledge assumes curriculum significance because revisions now takes place so rapidly that they will occur not once but several times in the lives of our students. If they have been taught their physics, chemistry or biology dogmatically, their discovery that revision has occurred can only lead to bewilderment and disaffection. Again, the alternative is the teaching of scientific knowledge in light of the inquiry that produced it.

Schwab (1962, p. 198) also expressed concern about the manner in which science is presented to students. He said, "the first significance to education is we cannot teach the conclusions of a discipline as if they were about the whole subject matter and were the whole truth about it."

In an earlier article he reviewed hundreds of research reports, including those of the most outstanding scientists of the past two centuries, in an endeavor to see what scientists do. He found that inquiry within disciplines changes with time and that the nature of the discipline had much to do with the type of inquiry used to study phenomena within that discipline (Schwab 1960).

Schwab (1964, p. 24) contended that the way to improve science teaching was to educate teachers in modes in inquiry. He said:

> The need for content of inquiry wherewith to make teaching and learning clear has been almost universally overlooked because of a singular failure in the subject matter preparation of teachers. They have been permitted to assume, or, indeed have been flatly told, that "induction" or "scientific method" stands for something simple, single and well defined. Quite the contrary is true: induction is not the name for some single, definite process but merely an honorific word attached by various philosphers to what ever mode of inquiry they favor.

Bruner concurred that training of teachers is indicated and that to accomplish this, education should enlist help. He stated (1960, p. 32):

> Designing curricula in a way that reflects the basic structure of a field of knowledge requires the most fundamental understanding of that field. It is a task that cannot be carried out without the active participation of the ablest scholars and scientists. The experience of the past several years has shown that such scholars and scientists, working in conjunction with experienced teachers and students of child development, can prepare curricula of the sort we have been considering. Much effort in the actual preparation of curriculum materials, in teacher training, and in supporting research will be necessary if improvements meet the challenges of the scientific and social revolution through which we are now living.

The result of these recommendations is now history. Hurd (1969, p. 14), in discussing the direction the reform was to take, said:

> The National Science Foundation, which had been asked by the Congress of the United States to make the decision, chose the professional scientist as the most qualified person to improve high school science courses. For example, the research physicist is the person who knows physics best and is therefore the one to revitalize the physics course; the same rationale was used to select directors for writing 'new' biology, chemistry and earth science courses.

The selection of scientists to head the projects resulted in curricula as recommended by the structure of disciplines movement. Hurd (1969, p. 16) described the new curricula saying:

> The scientist's point of view on curriculum development is quite clear: a high school course should be the mirror image of a science discipline, with regard to both its conceptual structure and its pattern of inquiry. The theories and methods of modern science should be reflected in the classroom. In teaching science, classroom operations should be in harmony with its investigatory processes and supportive of the conceptual, the intuitive, and the theoretical strucutre of knowledge.

The direction of the curricula reforms was clear but the effect on education practice was questionable. In a recent article, Goodlad (1979, p. 343) said, "Yet there is growing suspicion that the much touted supposed reforms of the sixties never occurred ... They were for the most part non-events."

Silberman (1970, p. 172) expressed this same view saying, "One needs only sit in the classrooms, in fact, and examine the text and reading list to know that with the possible exception of mathematics, the curriculum reform movement has made a pitifully small impact on classroom practice."

Not everyone views the curriculum reforms of the past two decades as failures. Shulman and Tamir (1973, p. 1130) stated:

> The impact of the new curricula is being felt not only because they produce an abundance of instructional materials, but also because they influence commercial writers to update their materials and motivate considerable improvements in teaching methods and facilities. Moreover, many students, teachers, colleges, and teacher training courses not officially committed to the new curricula have made extensive use of the instructional materials of the curricula. In this way new programs have had direct or indirect influences on most of the science teaching programs in the country.

Discovery Learning

In discussing the efforts of the curricula reforms to keep pace with rapidly changing knowledge, Hurd (1969, p. 34) said, "The current educational emphasis upon creativity, inquiry, intuitive interpretations, learning to learn, independent study, discovery and autonomous learning are each reflections of this point of view."

Discovery learning was closely associated with the curricula reform of the sixties which is not surprising since Bruner was one of the major proponents of discovery learning.

Bruner (1961, p. 22) defined discovery learning as, "Not only the act of finding out something that before was unknown to mankind, but rather including all forms of obtaining knowledge for one self by the use of ones' own mind."

In a later work Bruner (1966, p. 96) states, "Children need not discover all generalizations for themselves, obviously. Yet we want to give them opportunity to develop a decent competence at it and a proper confidence in their ability to operate independently."

Discovery learning is seen in a different manner by writers, for example Glasser (1966, p. 15) stated, "Discovery sequences can generally be characterized by these two properties: (1) inductive sequence and (2) trial and error or errorful learning."

Ausubel (1968, p. 292) viewed discovery learning as a change in educational objective and stated:

> The development of problem solving ability is, of course, a legitimate and significant educational objective in its own right. Hence, it is highly defensible to utilize a certain proportion of classroom time in developing appreciation of and the facility in the use of the scientific methods of inquiry and of other empirical inductive, and deductive problem solving procedures. But this is a far cry from advocating that the endearment of problem solving ability is the major function of the school. The goals of the scientist and student are not identical. Hence, students cannot learn science effectively by enacting the role of junior scientist.

The enhancement of problem solving as a major function of the schools was referred to in a statement by Suchman (1961, p. 198) in which he said:

> ... more basic than the attainment of concepts is the ability to inquire and discover them autonomously. ...The schools must have a new pedagogy with a new set of goals which subordinate retention to thinking. Instead of devoting their efforts to storing information and recalling it on demand, they would be developing the cognitive functions needed to seek out and organize information in a way that would be most productive of new concepts.

Gagné agreed with Ausubel in stating that most types of learning are best achieved by direct methods. He maintained that all learning except problem solving, can be learned through direct methods and most likely more rapidly if direct methods are used. About problem solving, Gagné (1970, p. 150) stated, "Problem solving, when considered as a form of learning, requires discovery since the learner is expected to generate a novel combination of previously learned principles. In this case too, guidance appears to have its familiar role of reducing time for search."

Skinner (1968, p. 109) expressed his disdain for discovery learning stating:

> If the student must be taught from the world of things, nothing will ever have to be taught. This is the method of discovery. It is designed to absolve the teacher from a sense of failure by making instruction unnecessary, the teacher arranges the environment in which discovery is to take place, he suggest lines of inquiry, he keeps the student within bounds. The important thing is that he should tell him nothing.

The lack of agreement about the role of discovery learning is not surprising when one recognizes the impact of psychology on the science curriculum reform. Shulman and Tamir (1973, p. 1110) stated, "During the recent years of the science teaching revolution, decisions about instruction have most often been explicitly rooted in or at least rationalized by reference to some form of psychological theory."

Research on Discovery Learning

The literature contains a multitude of experiments conducted on discovery learning. However, Wittrock (1966, p. 68) after reviewing over fifty of the early studies said:

> ... results of a study should be generalized only to students, subject matter, and situation directly comparable to those sampled in the experiment. Although the future may show that broad principles do encompass a variety of people and subject matter, the present state of science warrants no such conclusions.

Shulman and Tamir (1973), after a comprehensive review of science teaching reached the same conclusion.

Since generalizing results from one subject matter to another, and one age group to another is dubious, only selected literature pertaining to the effects of discovery learning in high school or first college courses in chemistry were included in the review.

A computer search of the literature pertaining to discovery learning in secondary chemistry yielded the same results as Shulman and Tamir reported (1973, p. 1139). They summarized their findings by saying, "The bulk of research in science teaching during the past decade appeared to be dissertation-related one-shot studies by investigators for whom this would be their last research effort."

As the result there has been little replication of studies and contradictory results have been reported by researchers studying the same construct. However some factors were reported as significant by all who include them in their study. One of the factors was the independence of gender of student with achievement in chemistry (Gemberling 1975), (Hendricks 1962), (Homman 1961), and (Marking 1971).

Another factor that was consistently related to achievement in chemistry was the student's ability or background in mathematics. Bajah (1972), Demas (1977), and Maruo (1975) found significant correlations of mathematics standardized test scores with achievement in chemistry. Puzzuoli (1967), Hendricks (1962), and Kelly (1953) examined the relationship of years of high school mathematics with achievement in first college course in chemistry and found a significant relationship.

Several of the studies in high school chemistry compared students of the new curricula with those of conventional programs. These studies studied various aspects of chemistry instruction by comparing students of Chem Study and Chemical Bond Approach with students from conventional chemistry programs. One aspect of chemistry instruction studied was student achievement as measured by standardized chemistry achievement tests.

Schaff (1968) classified questions on the American Chemical Society National Science Teacher Association's (ACS/NSTA) high school chemistry exam according to levels within Bloom's cognitive domain. He reported no differences at the knowledge level; however, students of the modern curricula performed better on questions calling for intellectual skills above the knowledge level.

Troxel (1968) studied thirteen hundred and thirty-three students from classrooms of high schools with populations of more than five hundred students. He found that students of Chem Study and Chemical Bond Approaches (modern curricula) achieved better as measured by the ACS/NSTA test. Similar results were reported by Marking (1971) and Cottingham (1970).

Altendorf (1965) used a match pair design to compare achievement of traditional and Chem Study students. He matched students from four Chem Study classrooms with students of twenty-one traditional classrooms, using the Iowa Test of Educational Development and grade level to select pairs. He reported no significant differences between achievement of Chem Study students compared to those in the traditional classrooms on the ACS/NSTA high school chemistry examination. Similar results were reported by Bajah (1972) and Diamond (1970).

Hein (1970) found that teachers of modern curricula spend more time on laboratory and provided more discovery learning experiences than those of conventional classrooms. Therefore, comparison of modern curricula with traditional curricula is at least, in part, an evaluation of discovery learning and increased laboratory work on achievement.

Holcomb (1971) designed discovery learning activities for freshman college students studying qualitative analysis in general chemistry laboratory. He reported that students instructed by the discovery method were more able to design a separation scheme for an unknown as well as to score higher on a four month retention test than those with explicit instructions.

Wiseman (1979) reported similar success with nonscience majors who were to discover through experimentation the kinetic molecular theory. The students were asked to perform a series of simple experiments demonstrating the properties of gasses, liquids, and solids. After the experiments, fifty percent of the students could write an essentially correct statement of the kinetic molecular theory. An additional forty percent could do so after post laboratory discussion, while ten percent remained with misconceptions. The exercise was repeated three successive years with the same results. Interest in this exercise was higher than interest in conventional exercises.

Herron (1971) studied fifty science teachers at a National Science Foundation Summer Institute and found that only eight of the fifty could demonstrate the concept of inquiry as presented in National Science Foundation materials they were using. He also noted that only two of the teachers could discuss inquiry in the broader context of science in general.

He (1971) also found that most teachers used the text book as the central portion of the course and expressed concern about the lack of time to cover material. Herron also noted that many of these science teachers referred to class structure by the traditional college division of lecture-lab.

In summary the research reported does not conclusively support discovery learning as superior to other methods of learning materials. One study indicated discovery learning activities may not be practiced as widely in classrooms as suggested by the extent of the adoption of modern curricula, which stress these activities.

Research Methods

Once an investigator has selected a problem for study, he must design a study to gather data to provide answers to the research questions. Kerlinger (1973, p. 408) suggested that many of these design problems are answers to practical questions such as, "Can the study be done with the facilities at the investigator's disposal? Can the variables be measured? Will it cost too much? Will it take too much time and effort? Will the subjects be cooperative?" As the investigator answers the questions above, the design of the study emerges.

The design of a study dictated by practical concerns often produces a design less than ideal. The first of these deviations from the ideal is the inability to use random samples. Kerlinger (1973, p. 129) discussed such samples:

> Another form of nonprobability sampling is purposive sampling, which is characterized by the use of judgment and a deliberate effort to obtain representative samples by including presumably typical areas or groups in the sample. So-called 'accidental' sampling, the weakest form of sampling, is probably also the most frequent. In effect, one takes the available samples at hand: classes of seniors in high school, sophomores in college, a convenient PTA and the like. This practice is hard to defend. Yet, used with reasonable knowledge and care, it is probably not as bad as said to be.

He goes on to say, "... if you do use them, use circumspection in analysis and interpretation of data." This implies that care should be exercised in generalizing results.

Campbell and Stanley (1963, p. 187) discussed the problem of generalizing results:

> Generalization always turns out to involve extrapolation into a realm not represented in one's sample. Such extrapolation is made by assuming one knows the relevant laws. Thus if one has an internally valid design 4, one has demonstrated the effect for only those specific conditions which the experimental and control group has in common, i.e. of for pretested group of a specific age, intelligence, sociometeric status, geographic region, historical moment . . .

However, later on in the same discussion they indicated that one can increase representativeness of samples in education by including more classrooms from which students are drawn for the study.

This study shares with many other educational studies the quasi-experimental, ex post facto design. The students either participated or failed to participate in discovery learning experiences before the investigation began. Campbell and Stanley (1963) term this one of the weakest of experimental designs.

Kerlinger (1973, p. 390) describes the limitations as he states:

> Ex post facto research has three major weakness ... 1) the inability to manipulate independent variables, 2) the lack of power to randomize and 3) the risk of improper interpretation. In other words compared to experimental research, other things being equal ex post facto research lacks control; this lack of control is the basis for the third weakness: the risk of improper interpretations.

He (1973, p. 392) later in the same discussion adds:

> It can even be said the ex post facto research is more important than experimental research. That is, of course, not a methodological observation. It means rather, that the most important social scientific and education research problems do not lend themselves to experimentation, although many of them do lend themselves to controlled inquiry of the ex post facto trend.

Campbell and Stanley (1963) also indicated that ex post facto research can be improved with the use of matching variables that contribute to the outcome variable. They contended that with the use of multivariable statistical analysis one can control for variance that may otherwise confound the treatment's effect. However, they also cautioned that if all variables are not accounted for the treatment effect may still be clouded with undefined contributing variables.

In discussing ex post facto research Kerlinger (1973, p. 318) made this point:

> An important distinction must be made. We are not saying that the method is universally worthless and misleading. In starting life we depend on such 'experimental' evidence. We act, we say on the basis of our experience, and this is the only way we can act. We hope we use our experience rationally and critically.

The brief review of literature on research design indicates that ex post facto designs are not the most commendable of designs; however, the results of such studies can be useful if one uses proper care in the analysis and interpretation of the data. The literature also indicates that the nature of educational research often dictates the use of such designs because the researcher does not have the ability to control or manipulate the necessary variables.

Summary

In this chapter the literature pertaining to major contemporary psychologies was reviewed, including the translation of these psychologies into learning theories. The literature indicates differences in what one psychologist accepts as sound instructional practice as compared with other contemporary psychologists. Also reviewed was the literature pertaining to the structure of science and the implications this structure has had for designing instruction in chemistry. The literature indicates that the writings of Schwab and Bruner concerning the structure of science and knowledge influenced the science curricula reforms of the sixties to a great extent.

The research reviewed indicated that some support has been found for activities that allow the student the opportunity to participate in discovery learning, although results are somewhat contradictory.

The literature on research design indicates, although the use of the ex post facto design has limitations, the results can be useful if proper care is exercised in the analysis and interpretation of the data.

CHAPTER 3

DESIGN OF THE STUDY

Introduction

The purpose of this chapter is to describe the design of the study. This chapter is divided into four sections: (1) description of sampling procedure; (2) development of instruments; (3) methods of gathering data; and (4) statistical procedure for the analysis of data.

Sampling Procedures

Students in the general college freshman chemistry course at the University of Arizona were selected as the population for this study. These students afforded the investigator the opportunity to gather the type of data necessary to conduct research.

The sample was drawn by administering the Learning Activities Questionnaire (Appendix A) to the lecture sections of a single instructor. The demographic data on the questionnnaire were used to select from these sections students with the following characteristics: (1) enrolled as freshmen at the University of Arizona; (2) enrolled in a college chemistry class for the first time; (3) studied secondary school chemistry at an Arizona high school; and (4) graduated from high school in 1978 or after.

The sections contained approximately 450 students, of which 365 completed questionnaires. Of these 365 questionnaires, 61 were not usable because students either did not complete the questionnaire or failed to sign the questionnaire, indicating they did not wish to participate in the study. Others were unusable because the students did not take high school chemistry, were sophomores, or out of state students. The result was a usable sample of 171 students.

Instrumentation

During the design of the study it was evident that there was not a questionnaire available that would obtain the necessary information about the subjects' high school chemistry backgrounds. The researcher designed a questionnaire to be validated by a committee of five specialists. Individuals who evaluated and aided in the construction of the questionnaire included:

Dr. Paul M. Allen, Professor of Secondary Education (and learning theory specialist).

Dr. George Babich, Assistant Director North Central Association School Visitor (and former secondary science teacher).

Dr. William D. Barnes, Professor of Secondary Education (and former secretary science teacher).

Dr. Robert J. Letson, Department Head, Secondary Education (and former superintendent of Curriculum).

Dr. Linda Bowen, Assistant Professor of Secondary Education (and education research specialist).

The Learning Activities Questionnaire was presented to the committee of five who suggested revisions in syntax and additional items dealing with learning activities that promote discovery learning. These suggestions were incorporated into the second draft, which also received recommendations for improvement of clarity and ease of response to items. These changes were used to produce the third draft which was deemed appropriate to the purposes of this study. A copy of the final questionnaire is included as Appendix A.

The Learning Resource Questionnaire was constructed to measure subjects' use of learning resources at the University outside of lecture and laboratory. Learning resources were identified and listed from interviews with the instructor of the freshman chemistry course. These resources included those arranged by the student, such as study groups or private tutors, those provided by the chemistry department, and those provided by Associated Students' Association. The last item on the questionnaire was an open-ended question which allowed the respondent to identify other learning resources outside the classroom and the extent of his/her use of these resources. A copy of this instrument is included as Appendix B.

Data Gathering Procedures

The first data were gathered by administering the Learning Activities Questionnaire to the selected sections during the first week of the 1981 fall semester. The instructor passed out the questionnaire and collected the returns within the same class session. This procedure yielded 171 usable questionnaires. The second questionnaire, the Learning Resource Questionnaire, was administered by the research during the fourteenth week of the semester. This questionnaire was administered and collected within a single class period. Questionnaires were obtained from 90 of the subjects in the study.

The next phase of the study was to interview 10% of the subjects. However, only 15 students volunteered for these interviews, which was 8.77% of the sample. A list of 10 questions was prepared (Appendix C) to provide structure for the interview. However, the subjects were encouraged to volunteer additional information in the area of the questions. The volunteers represented 15 different Arizona high schools and were very willing to discuss their high school chemistry experiences.

The fourth round of data gathering was to obtain information from the students' high school records in the University of Arizona Registrar's Office. The information was gathered from the records to be evaluated as covariates with the dependent variables. The following information was obtained; ACT Mathematics Score, ACT Natural Science score, ACT Composite score, year in high school that chemistry was studied, high school grade point average, and high school physics grade. Of the 171 subjects, there were 4 who had no high school record on file and 52 subjects without ACT test scores.

The final phase of data gathering was to obtain from the chemistry instructor lecture session test scores and laboratory scores. The test scores represented the sum of the hourly examinations plus the quizzes which were equivalent in points to one hourly examination. The laboratory scores represent the percentage of points students scored on written laboratory reports.

Method of Analysis of Data

Computer programs from the Statistical Package for the Social Sciences (SPSS) were used for analysis of data. Frequencies of all items on both Learning Activities Questionnaire (Appendix A) and the Learning Resource Questionnaire (Appendix B) were obtained.

Each questionnaire was also analyzed to obtain an estimate of the reliability using the Alpha split-half method from SPSS program.

The only statistical test not performed by the SPSS was the pairwise comparison of means, in which case a T-test of independent means was used.

The attribute variables, independent variable, and dependent variable were used to form a bivariate Pearson correlation matrix in order to select those attribute variables to be used to construct a hierarchical multiple regression equation to test the statistical hypothesis.

CHAPTER 4

ANALYSIS OF DATA

For the purpose of the analysis of data this chapter is divided into five sections. The first section will present a description of the sample, using the data from the Learning Activities Questionnaire (Appendix A) and the students' high school records. The second section will present the analysis of the Learning Activities Questionnaire, and the Learning Resource Questionnaire will be analyzed in the third section. The fourth section will summarize the comments of the fifteen students interviewed. The last section will present the statistical test for the three hypotheses of this study.

Description of the Sample

The sample was selected to be representative of freshmen students who had studied high school chemistry in an Arizona high school, graduated within the last three years and were enrolled in their first college chemistry course at the University of Arizona.

The sample is described in terms of information concerning high school background in science and mathematics, which was obtained from the Learning Activities Questionnaire and high school records. Data were not available on some subjects either because the subject did not respond to the item on the Learning Activities Questionnaire or because the information was missing from records on file in the registrar's office.

The first of the background variables used to describe the sample is presented in Table 1. The source is self-reported data from the Learning Activities Questionnaire.

Table 1. Number of Years of Science Completed in High School.

Years Completed	Number of Responses	Percent of Total
1	8	4.7%
2	33	19.3%
3	51	29.8%
4	61	35.7%
more than 4	15	8.8%
missing data	3	1.8%
TOTALS	171	100.1%*

*Not equal to 100% because of rounding error.

The next descriptive variable is the number of years of high schol mathematics. Data were obtained for all 171 subjects for this item. It is interesting to note that 60.8% of the students reported four or more years of high school mathematics. The source is self reported data from the Learning Activities Questionnaire.

Table 2. Number of Years of Mathematics Completed in High School

Years Completed	Number of Responses	Percent of Total
1	2	1.2%
2	16	9.4%
3	49	28.7%
4	89	52.0%
more than 4	15	8.8%
TOTALS	171	100.1%*

*Not equal to 100% because of rounding error.

Another variable indicative of student background and ability is the American College Test (ACT) Achievement Test Scores. These scores are reported percentile scores for college bound seniors. The test is scored in two subsections, mathematics and natural science, as well as offering composite scores. (The composite score is a composite of the English, Mathematics, Natural Science, and Social Sciences sub-tests.) Table 3 presents these data for the subjects, obtained from their University of Arizona admission files.

Table 3. Means and Standard Deviations of ACT Test Scores.

Test Scores	Number of Cases	Mean	Standard Deviation
Mathematics	111	71.68	22.47
Natural Science	111	71.96	21.79
Composite	111	71.57	23.20

The mean of the 159 subjects for whom high school grade point average was available was 3.48, with a standard deviation of .68 (an "A" average is represented by 4.00). Some students had grade point averages greater than 4.0 because some schools represented in the sample award honor points for participating in advance placement courses.

One should note that, as a group, the subjects had a strong background in science and mathematics and are above average on two indicators of academic ability, ACT test scores and high school grade point average.

Analysis of Learning Activities Questionnaire

The Learning Activities Questionnaire was analyzed to determine validity and reliability. Content and construct validity were established by submitting the questionnaire to a panel of five experts within the field. This procedure is described in Chapter 3.

An estimate for concurrent validity was also obtained. Concurrent validity is defined as, "the extent to which test performance is related to some other current performance" (Gronlund 1965, p. 71). This estimate was obtained by comparing the responses on the Learning Activities Questionnaire with the results of the interviews with the fifteen students. The students interviewed reported the same general areas of emphasis for both activities that promote discovery learning and activities that do not promote discovery learning, as were obtained from the Learning Activities Questionnaire. This information was obtained from the same subjects but at different times and served to establish concurrent validity.

An instrument must not only be valid, but must yield reliable measurements to be useful. Items 1-30 of the Learning Activities Questionnaire were analyzed for reliability by the use of an SPSS program (Hohlen 1979) for determination of Chronbach's Alpha. This procedure resulted in a reliability coefficent of 0.98, denoting a high degree of consistency of the students' self reporting of learning activities at the high school level.

The Learning Activities Questionnaire was constructed to provide an index of a student's participation in learning activities that promote discovery learning. The questionnaire consisted of 30 items: 15 items represented learning activities that promote discovery learning, and the other 15 items represented activities which do not promote discovery learning.

The discovery index was constructed by scoring activities that promote discovery learning on the following frequency scale:

Three or more times per week	= 5
One or two times per week	= 4
Every other week	= 3
Two or three times per semester	= 2
Never	= 1

For items reporting activities that do not promote discovery learning the scale was reversed, resulting in the following frequency scores for each item:

Three or more times per week	= 1
One or two times per week	= 2
Every other week	= 3
Two or three times per semester	= 4
Never	= 5

One should note that frequent participation in activities that do not promote discovery learning decreases the discovery index score. The scales were scored in this manner because frequent participation in these activies decreases the likelihood that class time can be spent on discovery learning activities.

With the questionnaire scaled as described, the lowest score possible would be the number of items multiplied by one. This would yield a score of 30 but such a score would be an unlikely occurrence. The highest score possible would be the number of items multiplied by five, or 150, also an unexpected eventuality. The occurrences of scores at either extreme were not expected because the activities represented on each of the two 15 item scales represented more activities than classroom time available for participation in these activities. Also it is unlikely that a chemistry teacher would plan instruction making exclusive use of either activities that do not promote discovery learning or activities that promote discovery learning.

The scores obtained from the questionnaire ranged from 41 to 99 on the 171 questionnaires. The mean of these scores was 69.00, with a standard deviation of 8.75. These values were in the expected range, and indicated that the subjects participated in activities that promote discovery learning with varying frequencies.

Two subscores were obtained to compare the type of learning activities that promote discovery learning being used in the high school chemistry laboratory and classroom. The first of these was the sum of items 16, 17, 18, 20, and 27 which relate to laboratory activities. The other subscore was the sum of items 21, 23, 25, 26, and 28, which are indicative of learning activities in other-than-laboratory situations.

The range of scores on discovery learning activities associated with the laboratory ranged from 5 to 24, with a mean of 13.04 and standard deviation of 4.31. The other-than-lab discovery activities scores ranged from 5 to 20, with a mean of 9.98 and standard deviation equal to 3.17. A T-test of independent means gave a "T" of 23.1.20, with 336 degrees of freedom. The probability of this occurring by chance is much less than one in a thousand, indicating that these means are different.

Frequencies on individual items indicate that lecture is still an important part of instruction in high school chemistry. For example, item 7 asked, "How often did you listen and take notes from the teacher's lectures?" Of 171 responses, 55% indicated they participated in this activity three or more times per week, and another 35.7% indicated they participated one or two times per week. This indicated that 80.7% of the subjects spent at least one day a week in listening and taking notes from the teacher's lecture.

If the scoring of the Learning Activities Questionnaire is reversed, such that participation in activities that do not promote discovery learning is scored as five for "three or more times per week", four is "one time per week" and so on, and items representing discovery learning activities scores as one for "three or more times per week" on up to five for "never", an index for participation in non-discovery activities is formed. The scores resulting from this procedure ranged from 61 to 126, with a mean of 108.97 and standard deviation equal to 9.74. The mean of discovery index was 69.00 and a T-test of independent means indicates these means are different with a probability of less .001 that this difference could occur by chance. This difference indicates students spent more class time on activities that do not promote discovery learning than they spent on discovery learning activities.

Analysis of the Learning Resource Questionnaire

The Learning Resource Questionnaire (Appendix B) was constructed to measure the subjects' use of learning resources outside the classroom while enrolled in freshman college chemistry. The items were selected after identifying the learning resources available to chemistry students at the University of Arizona.

The learning resources listed seemed to be exhaustive, as only 19 of the 90 questionnaires indicated additional resources on the open-ended item 10, "Other resources--please specify." Of the 19 other sources specified, 13 were printed materials, as asked for in item 2 of the questionnaire. The other 6 were either family members or friends and could have been included in response to item 4. Since 42 of the 90 subjects returning questionnaires left item 10 blank, the item was not used in analysis of the Learning Resource Questionnaire.

The SPSS reliability program (Hohlen 1979) was used to calculate Chronback's Alpha for the Learning Resource Questionnaire. A reliability coefficient of .70 was obtained. This is a smaller reliability coefficient than that obtained from the Learning Activities Questionnaire which may be due to the shorter length of the Learning

Resource Questionnaire. "In general, the longer the test (instrument) the higher the reliability" (Gronlund 1965, p. 90).

The Learning Resource Questionnaire was scored on the following frequency scale:

One or more times per week	= 4
Before each exam	= 3
Occasionally but not on a regular basis	= 2
Never	= 1

The score for the Learning Resource Questionnaire was obtained by summing items 1 through 9. The range of scores possible was from a minimum of 9 to a maximum of 36. The 90 scores obtained ranged from 9 to 24, with a mean of 14.60 and standard deviation equal to 3.92. Note that a score of 9 indicates the subject used none of the resources listed on the questionnaire.

Analysis of Student Interviews

The students of each section selected for this study were asked to volunteer for an interview concerning their high school chemistry background. This request produced 15 volunteers, all subjects of this study.

Each volunteer was interviewed by the researcher during the fall semester, using the ten Interview Questions (Appendix C) to provide structure. The students were encouraged to volunteer additional information in the areas of the questions. A summary of their responses, and where appropriate; comments, for these ten questions as follows:

Question 1. What is your college major?

Table 4. Students' College Majors

Major	Number of Students
Chemistry	1
Biochemistry	1
Engineering	5
Biological Science	3
Food and Nutrition	1
Pre-vet	1
Pre-dental	1
Animal Science	1
Earth Science	1

Question 2. In what year of high school did you study Chemistry?

The responses to this question were 5 during the sophomore year, 7 in the junior year, and 3 in the senior year. These results are consistent with information from student records which indicated that for 162 students, 20.4% studied chemistry in their sophomore year, 58.6% in their junior year and 21% during their senior year.

Question 3. What type of learning atmosphere was present in your high school chemistry class?

All 15 students agreed that the atmosphere was relaxed. Some additional students comments were: "Perhaps too relaxed. Our teacher was president of the union and often was as much as 30 minutes late." "Very relaxed, lots of humor and the teacher had good rapport with the students."

Question 4. What were your high school laboratory experiments like?

The students responded to this question by describing the written materials used in laboratory. Of the 15 students, 7 reported using a laboratory manual and 8 worked from handouts provided by the teacher.

Question 5. How did you report laboratory data?

Table 5. Method of Reporting Data

Method used to report data	Number of Students
Formal laboratory report with analysis of data	9
Just gave results to teacher	3
Account for errors and answer specific questions	1
Used carbon paper, filled in the blanks, handed one copy in and kept the other	1
We only did lab reports second semester	1

Question 6: Which of the following topics do you remember doing: Empirical formulas, percent composition, pH, balancing equations, stoiciometric relationships, heats of formation, kinetics, acid-base equilibria, normality?

The responses to this question were so varied that no pattern was evident. One person reported having done none of the topics while the others reported different combinations of the topics.

Question 7. What kind of problems did you do from the text book?

All of the subjects reported they did mostly mathematical type problems from the text book and typically had weekly assignments with this type of problem.

Question 8. Did you solve problems that required application of concepts, but not necessarily mathematics?

All but one of the students indicated they did very few of these types of problems. They reported that the few they remember doing were included in laboratory exercises. The one exception said, "Yes we did this type of problem every day. We did many problems requiring application of concepts to different circumstances."

Question 9. If we were to divide college chemistry into three areas, lecture-test, problem solving, and laboratory, which area would be most difficult for you?

Of the 15 students polled, 6 indicated they found problem solving activities in freshman college chemistry the most difficult. These students indicated that their problems were mostly in the area of mathematical procedures rather than application of the concepts of chemistry.

The lecture-test portion was chosen by 3 students. One of these students indicated difficulty in adjusting to the multiple choice question format of the examinations.

The remaining 6 students reported having the greatest difficulty in laboratory activities. Of these students, 2 identified problems in relating the laboratory portion of freshman chemistry with the lecture portion and vice versa. After having indicated laboratory as the area most difficult, one student commented, "I did not have enough experience in high school laboratory. Very little thought is involved in filling in the blanks."

Question 10. If you were to recommend changes to your high school chemistry teacher what would they be?

Student comments were: "More intense treatment of some topics. Really get into relationships. Cover some topics that can't be completely understood but will be covered in freshman chemistry." "More work related to understanding concepts and applying those concepts in laboratory experiments. I discovered some relationships but probably missed many others." "We spent too much time memorizing materials and did not spend enough time understanding what we were doing." "Advance at a faster rate." "I took high school chemistry my sophomore year. I think I would have done better if I would have taken it later in high school." "Cover more topics and go into more depth." "We spent too much time on molar problems and equation balancing, which excluded other important topics." "We could have done with a few more experiments. We shared the laboratory with another class so didn't do as much lab as needed." "A little more theory and lecture." "Offer an advanced chemistry course." "Push a little harder."

After analyzing the comments of the 15 students interviewed the following observations can be made:

1. Students have a wide variety of experiences in high school chemistry.
2. Students reported a relaxed learning atmosphere in their high school chemistry class.
3. The comments obtained through these 15 interviews were consistent with the information obtained from the Learning Activities Questionnaire.

Statistical Test of Hypothesis

The first statistical hypothesis to be tested was:

There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in lecture-recitation portion of freshman college chemistry.

The extent of students' participation in discovery learning activities were represented by the discovery index, which were the scores obtained from the Learning Activities Questionnaire (Appendix A). Their performance in the lecture-recitation portion of freshman college chemistry was represented by the sum of their examination scores from the lecture portion of freshman chemistry.

A hierarchical multiple regression procedure was performed with examination scores as the dependent variable. Before entering the discovery index score the following covariates were removed in the order listed: years of high school science, college chemistry laboratory scores, American College Test (ACT) mathematics scores, and high school grade point averages.

The hierarchical procedure of multiple regression removes the variance for each of the covariates from the dependent variable as they are entered in the multiple regression equation (Nie et al. 1975, pp. 320-343). This allows one to account for variance that might otherwise obscure the relationship of the independent variable of interest, in this case the discovery index, with the dependent variable, examination scores in the lecture portion of freshman chemistry. The results of the procedure are summarized in Table 6.

Once the multiple regression procedure was accomplished, two measures of relationship were obtained. The first of these measures was the change in R^2, which is the indication of the variance accounted for by the addition of that variable to the multiple regression equation. With discovery index scores as the independent variable, and lecture-recitation examination scores as the dependent variable, the addition of discovery index resulted in a change in R^2 of .01; or only accounted for 1% more of the variance in examination scores.

The second measure of relationship was the partial correlation of discovery index scores, after the variance of preceding covariates was removed, with examination scores. As described in Table 6, this yields an F-ratio with K, N-K-1 degrees of freedom. This F-ratio indicates the probability of obtaining the partial correlation by chance when the true correlation is equal to 0. As presented in

Table 6. Multiple Regression Summary Table for College Chemistry Examination Scores.

Step[a]	Variable Entered[b]	F-Ratio to Enter[c]	df[d]	Significance[e]	Multiple R[f]	R^2[g]	Change in R^2[h]	r[i]	Partial R[j]
1	YSCI	5.141	1,97	.026	.22	.05	.05	.22	----
2	LSC	34.359	2,96	.000*	.55	.30	.25	.53	.51
3	ACM	26.842	3.95	.000*	.67	.45	.15	.58	.47
4	GPA	7.578	4,94	.007	.70	.49	.04	.45	.27
5	DSI	.972	5,93	.327	.71	.50	.01	-.04	-.10

*Computer program calculates probability to thousandths, these probabilities are less than .001.

[a] Step: order of entry of variable in the regression equation.

[b] Variable entered: YSCI, years of high school science; LSC, college chemistry lab score; ACM, ACT mathematics score; GPA, high school grade point average; DSI, discovery index from Learning Activities Questionnaire.

[c] F-ratio to enter: Calculated from $\frac{\text{incremental sums of squares for variable being entered} \div K}{\text{sums of squares residual} \div (N-K-1)}$

Where K = number of independent variables, including the constant in the regression statement.
N = number of cases
This same F-ratio is used to determine significance of the partial correlation.

[d] df: degrees of freedom for F-ratio, K and N-K-1

[e] Significance: probability of obtaining F-ratio by chance.

[f] Multiple R: multiple correlation coefficient

[g] R^2: coefficient of determination calculated from multiple correlation coefficient.

[h] Change in R^2: change in R^2 produced as this independent variable is entered.

[i] r: correlation of independent variable with dependent variable.

[j] Partial R: partial correlation of variable being entered with dependent variable, after variance is removed for covariates already in the equation.

Table 6, the partial correlation was -.10 with an F-ratio equal to .97, degrees of freedom 5,93, and probability equal to .327, not significant at .05 level. The statistical decision was to retain the null hypothesis: There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in lecture-recitation portion of freshman college chemistry.

An advantage of using the hierarchical procedure was the ability to note the change in the partial correlations of the discovery index scores with the addition of each of the covariates. Table 7 summarizes these data.

Table 7. Partial Correlations of Discovery Index Scores with Examination Scores as Covariates are Added to Multiple Regression Equations.

Covariate[(a)]	Partial Correlation	F-Ratio	df	Probability
YSCI	-.08	.631	2,96	.429
LSC	-.16	2.651	3,95	.107
ACM	-.09	.814	4,94	.369
GPA	-.10	.972	5,93	.327

[(a)] Covariates: YSCI, years of high school science; LSC, college laboratory score; ACM, ACT mathematics score; and GPA, high school grade point averages.

The data in Table 7 indicate that the partial correlation made small changes as the covariates were entered, but never achieved a significant F-ratio at the .05 level of significance. These data support the retention of the null hypothesis.

The second hypothesis to be tested was:

> There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in freshman college chemistry laboratory.

Again the discovery index scores were used to measure student participation in discovery learning activities. These scores were entered in the regression equation after variance due to years of high school mathematics, ACT mathematics test scores, college chemistry examination scores, and high school grade point averages were removed from college laboratory scores. The results of the procedure are displayed in Table 8.

The addition of the discovery index scores improved prediction by 3%, as indicated by the .03 change in R^2. This procedure yielded a partial correlation of discovery index scores with college laboratory scores of .20 after the variance due to the covariates were removed. The F-ratio for the partial correlation was 3.995 with 2,93 degrees of freedom and significant at the .05 level. Based on this statistical evidence the null hypothesis was rejected, leading to the acceptance of an alternate hypothesis: There is a relationship between the extent of students' participation in discovery learning activities in high school chemistry and their performance in freshman college chemistry laboratory.

Table 8. Multiple Regression Summary Table for College Chemistry Laboratory Scores.

Step[a]	Variable Entered[b]	F-Ratio to Enter[c]	df[d]	Significance[e]	Multiple R[f]	R^2[g]	Change in R^2[h]	r[i]	Partial R[j]
1	YMA	1.687	1,97	.197	.13	.02	.02	.13	----
2	ACM	14.457	2,96	.000*	.38	.14	.12	.38	.36
3	TSC	18.853	3,95	.000*	.54	.29	.15	.53	.41
4	GPA	.115	4,94	.735	.54	.29	.00	.28	.04
5	DSI	3.995	5,93	.049	.56	.32	.03	.14	.20

*Computer program calculates probability to thousandths, these probabilities are less than .001.

[a] Step: order of entry of variable in the regression equation.

[b] Variable entered: YMA, years of high school mathematics; ACM, ACT mathematics score; TSC, college chemistry test score; GPA, high school grade point average; DSI, discovery index from Learning Activities Questionnaire.

[c] F-ratio to enter: Calculated from

$$\frac{\text{incremental sums of squares for variable being entered} \div K}{\text{sums of squares residual} \div (N-K-1)}$$

Where K = number of independent variables, including the constant in the regression statement.
N = number of cases
This same F-ratio is used to determine significance of the partial correlation.

[d] df: degrees of freedom for F-ratio, K and N-K-1

[e] Significance: probability of obtaining F-ratio by chance.

[f] Multiple R: multiple correlation coefficient

[g] R^2: coefficient of determination calculated from multiple correlation coefficient.

[h] Change in R^2: change in R^2 produced as this independent variable is entered.

[i] r: correlation of independent variable with dependent variable.

[j] Partial R: partial correlation of variable being entered with dependent variable, after variance is removed for covariates already in the equation.

The change in the partial correlations of discovery index scores with laboratory scores as each of the covariates were added to the regression equation are exhibited in Table 9.

Table 9. Partial Correlations of Discovery Index Scores with Laboratory Scores as Covariates are Added to Multiple Regression Equation.

Covariate[a]	Partial Correlation	F-Ratio	df	Probability
YMA	.12	1.450	2,96	.231
ACM	.19	3.648	3,95	.059
TSC	.20	4.123	4,94	.045
GPA	.20	3.995	5,93	.049

[a]Covariates: YMA, years of high school mathematics; ACM, ACT mathematics score; TSC, college chemistry examination score; GPA, high school grade point averages.

It is interesting to note that once years of high school mathematics and ACT mathematics scores had entered the equation the partial correlation of discovery index scores increased very little and became significant at the .05 level. The addition of college examination scores increased the partial correlation only slightly although as the data in Table 8 indicate, it had a simple correlation of .53 which was higher than any of the other covariates.

The final statistical hypothesis to be tested was:

> There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their use of learning resources of freshman college chemistry.

The students' participation in discovery learning activities was again measured by the discovery index scores and the use of learning resource scores by the Learning Resource Questionnaire (Appendix B).

The multiple regression procedure used to test the previous two statistical hypotheses was not useful for testing this hypothesis because of the lack of suitable covariates among the attribute variables of this study. The three variables with the largest correlations were ACT mathematics scores, ACT natural science scores, and ACT composite scores. The correlations were, -.24, -.38 and -.26 respectively. All were significant at the .05 level and moderately intercorrelated with each other. Because these variables were intercorrelated they were not useful as covariates for a multiple regression equation.

The bivariate Pearson Correlation of discovery index scores with Learning Resource Questionnaire scores was .15 with a probability of .077 that this correlation could be obtained from population in which the correlation was 0. Although the correlation is in the expected direction it was not significant at the .05 level so the null hypothesis was retained: There is no relationship between the extent of students' participation in discovery learning activities in high school chemistry and their use of learning resources of freshman college chemistry.

Summary

Chapter 4 was divided into five sections for the analysis of data, the first was a presentation of data describing the sample. These data indicated the subjects of this research were well prepared in science and mathematics and above average on two measures of academic achievement, ACT test scores and high school grade point averages.

The second section presented the analysis of the Learning Activities Questionnaire which indicated that students participated in activities that promote discovery learning with varying frequencies, with more participation in these types of activities in the laboratory portion of high school chemistry.

The Learning Resource Questionnaire was analyzed in the third section. It was noted that some students reported using none of the resources listed on the questionnaire while others made comparatively extensive use of these resources. The next section presented the analysis of the student interviews and noted that this information was consistent with information obtained from the Learning Activities Questionnaire.

The final section presented the statistical treatment of data for testing the hypotheses. The analysis of these data indicated that the extent of students' participation in activities that promote discovery learning, as measured by the discovery index, was significantly related to college chemistry laboratory scores but not related to either the college chemistry examination scores or students' use of learning resources outside lecture and laboratory at the University.

CHAPTER 5

SUMMARY, DISCUSSION AND RECOMMENDATIONS

Summary

The Problem

The purpose of this study was to assess the extent of discovery learning opportunities in Arizona secondary chemistry classrooms and to determine their relationship to performance in selected areas of freshman college chemistry at the University of Arizona.

Methods of Gathering Data

For the purpose of this study two questionnaires were developed, one to gather data relating to students' participation in learning activities in high school chemistry and the other to assess their use of learning resources available to them at the University of Arizona. The Learning Activities Questionnaire (Appendix A) was administered to selected sections of freshman college chemistry classes and the subjects were selected. Later in the same semester the Learning Resource Questionnaire (Appendix B) was administered to gather data on the subjects' use of learning resources outside the classroom.

Interviews were conducted with 15 volunteers from the subjects of this study. The volunteers were asked questions about their high school chemistry class. These data were tabulated and found to be consistent with data from the Learning Activities Questionnaire.

Data were acquired from the subjects' high school records for evaluation for possible use as covariates with the independent variables of the study.

Examination and laboratory scores were obtained from the records of the chemistry instructor, to assess student performance in lecture and laboratory.

Analysis of Data

The students' responses to the items on the Learning Activities Questionnaire were analyzed to determine the extent of their participation in high school chemistry in activities that promote discovery learning. A discovery index score was calculated for correlation with college chemistry examination scores, college laboratory scores, and student-reported use of learning resources.

The relationship of the discovery index scores with college freshman chemistry examination scores was analyzed by the use of a hierarchical multiple regression equation. Years of high school science, college laboratory scores, ACT mathematics scores, and high school grade point averages were used as covariates. The partial correlation of -.10 was not significant at the .05 level of significance.

A similar hierarchical multiple regression equation was used to determine the relationship of the discovery index scores to college chemistry laboratory scores. The covariates were years of high school mathematics, ACT mathematics scores, and high school grade point averages. A partial correlation of .20, significant at the .05 level, indicated there was a statistically significant relationship between discovery index scores and college laboratory scores.

It was not possible to use a multiple regression analysis for testing the relationship of discovery index scores to Resource Questionnaire scores due to the lack of suitable covariates. A Pearson bivariate correlation of .15 between these two variables was not significant at the .05 level.

Discussion of Findings

The findings of this study are discussed in terms of the questions that provided direction for the study. The findings can be generalized with respect only to the population of this study, that is, Arizona high school graduates enrolled in freshman college chemistry at the University of Arizona.

Question 1. To what extent are students afforded the opportunity to participate in discovery learning activities in Arizona secondary chemistry classrooms?

The data from the Learning Activities Questionnaires indicate that students reported participation in learning activities that promote discovery learning with varying frequency. The range of scores suggests that in some classrooms participation in these kinds of activities was infrequent. More students identified participating in these kinds of activities in association with laboratory experiences rather than other portions of chemistry instruction.

The more frequent participation in activities that promote discovery learning in association with laboratory activities may be in part due to the influence of the science curricula reforms of the sixties. One of the areas of emphasis during these reforms was on the type of laboratory activities associated with the new curricula. These laboratory exercises tended to provide less explicit directions to the students and afforded the opportunity for the students to organize and report the data without providing blanks or structured charts. Further support for the existence of this influence came from the interviews with the students. Over half of these students reported using duplicated materials from the teacher rather than a laboratory manual. Of the students reporting the use of a laboratory manual, only one reported a manual which provided blanks and charts to be filled in during the course of the laboratory exercise.

Arizona chemistry teachers' presentation of learning activities in other than the laboratory part of the course is, in a large part, learning activities that do not promote discovery learning. However, care must be exercised in interpreting the dominance of these types of activities. For example, students made no distinction between lecture and group problem solving activities, in which they were guided as they mentally processed information to obtain solutions to problems involving the application of chemical concepts. Distinguishing between lecture and this type of activity would require direct classroom observation and was beyond the scope of the research.

Question 2: What is the relationship between participation in discovery learning activities in secondary chemistry and performance in lecture-recitation section of college freshman chemistry?

The failure to find a significant correlation between discovery index scores and college lecture-recitation examination scores provides some interesting implications. The lack of correlation of these two variables implies that students' participation in learning activities that promote discovery learning neither improved nor decreased their examination scores. This is consistent with the studies reported in Chapter 2 in which students participating in discovery learning activities were compared to students that were taught by the expository method. No significant differences in achievement were detected.

A factor that may have affected this lack of relationship is the students' infrequent participation in discovery learning activities in non-laboratory portions of high school chemistry. This supports the suggestion of some writers that much of the supposed reforms of the sixties in science education were never implemented in the classroom.

Question 3: What is the relationship between participation in discovery learning activities in secondary chemistry and laboratory performance in college freshman chemistry?

This study indicated a significant relationship between participation in discovery learning activities in high school chemistry as measured by the discovery index scores, and college chemistry laboratory scores.

The relationship, as indicated by the partial correlation, was a positive correlation of .20 between the discovery index scores and the laboratory scores. Not only is this correlation statistically significant but it is practically significant, when one considers that only a small portion of students' high school backgrounds is represented by their high school chemistry class.

Another factor to be considered is that, with the use of the attribute variables of this study, laboratory scores are less predictable than lecture-recitation test scores. The multiple correlation coefficient obtained for college chemistry laboratory scores was .56, compared with a multiple coefficient for test scores of .71. The attribute variables, indicative of academic preparation and achievement, do not predict laboratory scores as well as they predict test scores. It is interesting to note that the kinds of learning activities in which students participated in their high school chemistry are independent of ability and background and are related to college laboratory scores.

The difference in correlation of discovery index scores with college examination scores and college laboratory scores may also indicate that there is a difference in knowing "about" chemistry and knowing "how to do" chemistry. If one accepts the proposition that high school chemistry needs to prepare students in both areas, then it would seem that learning activities that promote discovery learning have a role in the high school chemistry classroom, as do the other types of learning activities.

Question 4. What is the relationship between participation in discovery learning activities and the students' use of learning resources of college freshman chemistry?

The lack of suitable covariates among the attribute variables for inclusion in a multiple regression equation suggested the use of a Pearson correlation for the test of relationship. A Pearson correlation of .15 was obtained which was not significant at the .05 level. This implies that the high school students' participation in activities that promote discovery learning has no relationship to the students' subsequent use of learning resources in college chemistry.

Recommendations

After completing this study it appears that several recommendations are appropriate.

1. The correlation of the discovery index scores with the college laboratory scores suggests that activities that promote discovery learning have a role in preparing high school students for college laboratory exercises. The lack of correlation of discovery index scores with college chemistry examination scores imply that using class time in high

school classrooms for these types of activities do not significantly effect students' achievement in the lecture-recitation part of freshman chemistry. Since evidence from this study indicates that activities that do not promote discovery learning are more prevalent in Arizona chemistry classrooms, it is recommended that Arizona high school chemistry teachers seek ways to incorporate learning activities that promote discovery learning into their classrooms.

2. The Learning Activities Questionnaire is useful for obtaining a broad overview of high school chemistry instruction. It is recommended that it be used to detect changes in high school chemistry instruction as time progresses.

3. It is recommended that a means of determining specific laboratory skills be devised and used to determine the relationship of these skills to high school academic preparation as well as learning activities in high school chemistry classroom.

APPENDIX A

LEARNING ACTIVITIES QUESTIONNAIRE

Learning Activities Survey
Chemistry 103a - Sections 1,2,5,6

This questionnaire is a part of a study of learning experiences in high school chemistry. Your participation is voluntary and is in no way connected to your evaluation in this course.

Data will be gathered and reported in such a manner as to insure anonymity.

Please complete the following questionnaire if you have taken a high school chemistry course and have not completed a college chemistry course.

Signing your signature and the completion of this questionnaire indicates voluntary participation in this study.

____
Signature

Year in College: _____Freshman _____Sophomore _____Other
Was your chemistry class at an Arizona high school? ____Yes ____No
If yes, name of high school ______________________________
Number of semesters of high school chemistry.
_____1 semester _____2 (1 year) _____3 _____4 _____more than 4
School year you studied high school chemistry.
Before 1978-79_____ 1978-79_____ 1979-80_____ 1980-81_____
Years of science studied in 9th thru 12 grade, including chemistry.
_____None _____1 _____2 _____3 _____4 _____more than 4
Number of years of mathematics in high school.
_____None _____1 _____2 _____3 _____4 _____more than 4

The following statements refer to your learning experiences in high school chemistry. Please mark the one quantifier that best describes your participation.

How often did........

1. your teacher ask questions that required the recall of factual information?
three or more times per week_____ one or two times per week_____
every other week______ 2 or 3 times per semester_____ never_____

2. your teacher assign specific laboratory activities from a laboratory manual?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

3. your teacher assign specific questions at the end of a laboratory activity?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

4. your teacher assign problems and questions from the textbook?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

5. you work from a workbook or handout in which you filled in the blanks?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

6. you use programed materials? (Materials that use the answer to the last question to direct you to either new information or another explanation of previous concepts).
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

7. you listen and take notes from the teachers lecture?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

How often did........

8. you work on the same assignment as all other students?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

9. you read and study the textbook in preparation for an exam?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

10. your teacher ask you to memorize symbols, equations, or other general law?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

11. your teacher assign work from textbook to submit for credit?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

12. your teacher work sample problems for the entire class?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

13. you use your textbook or dictionary to write the definitions of words as a part of an assignment?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

14. you receive textbook reading assignments?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

15. your teacher explain the laboratory procedure before a lab?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester______ never_____

How often did........

16. you plan and conduct your own laboratory investigation?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

17. you write a laboratory report that analyzed the lab work in your own words?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

18. your analysis of laboratory data require you to construct your own charts, graphs, or diagrams?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

19. you work in the lab doing experiments?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

20. you plan an investigation to find an answer to a problem?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

21. you watch films that presented phenomena which you were asked to observe and analyze?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

22. you use written materials other than a textbook, workbook, or a laboratory manual?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

23. you discuss and study material not in the textbook?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

How often did........

24. you work on projects with other classmates, other than assigned lab partners?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

25. you read and write reports or discuss magazine articles on some topic in chemistry with the teacher and/or other students?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

26. you work independently on a project you selected?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

27. you organize data and develop statments generalizing the relationships of the data?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

28. you use sources outside the school to aid in solving a problem in chemistry?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

29. you have the opportunity to use the high school laboratory facilities to do an experiment of your own design?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

30. you plan the order in which you would study a topic?
three or more times per week_____ one or two times per week_____
every other week_____ 2 or 3 times per semester_____ never_____

The next statements ask for your general assessment of your high school chemistry course(s).

31. How did the methods of instruction in high school chemistry compare with other high school science classes?
    Entirely different_____ Somewhat different_____ Somewhat similar_____
    Very similar_____

32. How would you characterize your experience in high school chemistry?

    Very distasteful_____ One of the less interesting science classes_____
    Average science class_____ Above average science class_____
    Outstanding science class_____

APPENDIX B

LEARNING RESOURCE QUESTIONNAIRE

Learning Resource Questionnaire

Chemistry 103a Sections 1,2,5 & 6

Name___________________

This questionnaire is to determine your use of learning resources outside the lecture-recitation and laboratory portion of Chemistry 103a. Your participation is voluntary and is in no way connected to your evaluation in this course.

Data gained from this questionnarie will be reported in such a manner as to insure anonymity.

Below is a list of resources available to you outside of the regular classroom and laboratory portion of this course. Please indicate the extent of your use of these learning resources by checking the most appropriate blank.

How often do you use:

1. Study groups formed with one or more students from Chem.103a.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

2. Printed materials other than text or laboratory manual (includes workbooks, other textbooks, study outlines, previous students notes, examples of old test, etc.)

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

3. Tutorial sessions that Associated Students provide free at the University of Arizona.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

4. Tutorial sessions that you arrange for yourself.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

How often did you use:

5. Individual help from lecture instructor, outside of classroom time.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

6. Individual help from laboratory instructor, outside of classroom time.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

7. Study skills class provided by the chemistry department.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

8. Lecture instructors' Wednesday night review session.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

9. Computer aided instruction from PLATO in science library.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

10. Other sources, please specify _____________ _______________

_________________________.

_____one or more times per week _____before each exam

_____occasionally but not on regular basis _____never

APPENDIX C

INTERVIEW QUESTIONS

Name:

High School:

1. What is your college major?
2. In what year of high school did you study chemistry?
3. What type of learning atmosphere was present in your high school chemistry class?
4. What were your high school laboratory experiments like?
5. How did you report laboratory data?
6. Which of these topics do you remember doing?

   empirical formulas, percent composition, pH, balancing equations, stoiciometric relationships, heats of formation, kinetics, acid base equilibria, or normality
7. What kind of problems did you do from the text book?
8. Did you solve problems that required application of concepts, but not necessarily math?
9. If we were to divide college chemistry in to three areas; lecture-test, problem solving and laboratory, which is most difficult for you?
10. If you were to recommend changes to your high school teacher, what would they be?

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