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The effects of contingency management on the attainment of performance criteria in teaching high school chemistry.

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THE EFFECTS OF CONTINGENCY MANAGEMENT ON THE
ATTAINMENT OF PERFORMANCE CRITERIA IN TEACHING
HIGH SCHOOL CHEMISTRY

A Dissertation Presented

By

PIERRE PHILIP BARRETTE

Submitted to the Graduate School of the
University of Massachusetts in
partial fulfillment of the requirement for the degree of

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May 1971

Major Subject: Educational Media and Technology


THE EFFECTS OF CONTINGENCY MANAGEMENT OF THE
ATTAINMENT OF PERFORMANCE CRITERIA IN TEACHING
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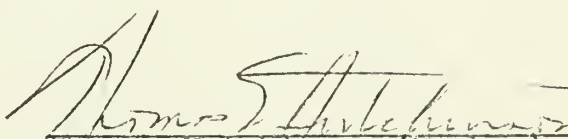
A Dissertation


By


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MAY 1971

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Two people, my father and Elise, each in their individual wisdom and collective counsel, have provided me with direction and perspective during critical points of my life. Their contributions are most sincerely appreciated.

Finally, it is only in the years ahead can I attempt to return the love, the understanding and the feeling that has so generously and so consistently been given by my wife. On the forthcoming anniversary of our fifth, but not last, child, this study is dedicated. De Colores.

A B S T R A C T

An experiment was conducted in which the effects of contingency management on the attainment of performance criteria in high school chemistry was assessed. The subjects were thirteen junior and senior high school students. A total of 35 experimental sessions ranging in time from 20 to 40 minutes long were run in which subjects constructed responses to items related to performance objectives in Chemistry. There were four experimental phases, Baseline, phase I; Instatement of Reinforcing Contingency, phase II; Reversal, phase III and Reinstatement of Reinforcing Contingency, phase IV. A reinforcing contingency using immediate consequence of acceptable responses was employed for performances assessed during phase II and phase IV. Unacceptable responses were not consequence during these phases. Percentages of accurate responses were exchanged for letter grades.

Subject performances were observed with the use of an electro-optical performance monitoring system called a MIVR, (Mediated Interaction Visual Response) system. This system provides subjects with an overhead projector so that their emitted performances can be monitored, assessed and then contingencies employed as scheduled. Subjects used the system on an alternating basis.

This study differs from many behavior modification studies in that a single contingency of reinforcement was applied almost simultaneously to individual students in a group and the behaviors under investigation were associated with academic content in the area of high school chemistry. No previous studies have reported the application of behavior modification to the teaching of high school chemistry.

The results for each of the thirteen students taken individually and also for the students taken as a group indicate that a higher percentage of accurate performances were emitted when explicit reinforcing contingencies were applied. When a reinforcing contingency was applied during phases II and IV, an increase in the percent of accurate emitted performances was observed for the group. When the reinforcing contingency was removed during phase III a decrease in accurate emitted performances to 36 percent was observed followed by an increase to 89 percent when the contingency was reinstated.

Results of the investigation indicate that under the conditions operating, an explicit reinforcing contingency can increase the percentage of accurately emitted performances by students taking high school chemistry.

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C H A P T E R I

INTRODUCTION

High School Chemistry. The development and emergence of new curricular programs in high school chemistry, such as the Chemical Bond Approach, (CBA 1964) and the Chemical Education Materials Study, (Chem Study, 1963), resulted in major revisions in traditional course content. The revisions in content were combined with a hope for increase in laboratory experimentation as a major instructional procedure. Both the revised content and the hope for emphasis on laboratory experimentation were designed to be implemented within the framework of traditional classroom scheduling practices. Within a decade after the two new programs became available for implementation, it was reported that over fifty percent of the nation's high schools had adopted the Chem Study version and a smaller percentage the CBA version, (Fornoff 1970).

Bennett and Pyke (1966), contrasted the two new programs. The authors stated that the traditional or conventional programs involved essentially the use of the classroom lecture and classroom demonstrations as major instructional procedures. These conventional procedures were combined with "recipetype workbooks," some laboratory work and "authoritarian teaching of facts." They also stated that the new

programs were characterized by the "great emphasis placed on laboratory work so that principles can be drawn directly from student experience".

Reports have emerged which seem to question the instructional procedures that were hoped for in the curriculum revision projects. Ramsey and Howe (1969a) in a comprehensive analysis of research on instructional procedures in secondary school science indicated that there was, "confusion between a course description (as outlined by a text or course of study) and the instructional procedures used to teach it". Brandwein (1969), after a five year study of secondary science education in the United States, indicated that:

Roughly 90 percent of the physics and chemistry and earth science teachers observe the lecture 90 percent of the time in the classroom.

Ramsey and Howe (1969b) also indicated that for the field of secondary chemistry, considerable research time had been devoted to comparative studies of achievement among the Chem Study, CBA and traditional courses but little time had been devoted to more basic research on chemistry instruction.

Research on chemistry instruction relied heavily on the course description providing the instructional procedure. There were no reports identified of research that evaluated different methods of using the CHEM study materials. Hopefully, this is the approach that future research will take, since the

evidence seems clear that in terms of knowledge outcomes, little difference can be detected between a traditional course and one of the newer courses.

In a more recent analysis of research focusing directly on the CHEM Study program, Ramsey (1970), reviewed both the objective and the subjective literature that had been published from 1960 to 1970. He criticized the lack of specific instructional procedures and stated the following:

The development section in the teacher's guide to the course outlines a detailed approach to each chapter. Stress is placed on experimental evidence and on models and analogies to help students understand concepts being considered in class. Although the teacher's guide is extremely detailed, the emphasis is on what to develop, and which models or experiments to use during development, rather than on describing teaching strategies which are known to be successful. There are many hints regarding what may be used in an instructional sequence, but few suggestions for blending the hints into a coherent whole to describe successful teaching strategies. It seems from the teacher's guide that it is left to the individual teacher to

express his own mode of instruction in the classroom.

He further commented on the lack of specific instructional procedures:

A course as different in content and approach as the CHEM Study program should be taught in the classroom in a way quite unlike that used to teach conventional courses. The course was to be based upon experimentation, ideas were to be developed inductively from evidence, and the emphasis was to be on understanding principles rather than on knowing facts. Yet a search of the literature has revealed no definite description of how these ideas were to be accomplished in the classroom. How does one teach inductively? What techniques are needed to develop understanding? Little attention has been directed to these urgent instructional questions and the newsletters or teacher's guide seem to leave them largely to the teacher's intuition.

Ramsey then summarized his analysis of research on the Chem Study program and suggested that attention should be directed at the teacher and how the teacher uses the material in the classroom.

From these comparative studies it seems that, in terms of the tests used, great gains in student outcomes were not obtained simply by changing to a new course. The teacher variable is likely to be a highly significant factor, and probably what the teacher does with the materials, rather than the materials per se may be more important in determining student outcomes. From the design of each of these studies it was evident that the teacher variable was only partly controlled. ... It seems unlikely that further studies which compare student achievement in new and conventional courses will produce any new knowledge, and attention should be directed at how teachers use the materials they choose in the classroom.

It seems apparent from Brandwein's statements that the lecture is the instructional procedure most often employed in teaching high school chemistry. It also seems apparent from Ramsey's statements that there has been a lack of research directed toward examining the teacher as a variable in the learning process and also what the teacher does with the material he selects for his students.

The limitations associated with using the lecture and the constraints imposed by traditional scheduling practices together with the treatment of students in classes or

groups, has prompted the development of new approaches to individualized instruction. The new approaches focus on a set of materials and activities that are related to the content area to be covered. The materials and activities are often combined into an instructional package. Individualized instructional packages usually included lists of specific performance objectives and these in turn are related to print and media resources. A student obtains a package and then is permitted to proceed through the material at his own rate of progress. (Bethune 1967a), (DeRose 1969, 1970a), (McCurdy and Fisher 1970).

The teaching of high school chemistry, whether using programs that are traditional or new, or the employment of individualized instructional packages, has limitations associated with each of them. These limitations exist in three broad areas. The first area is related to the practices that are employed to monitor student performances. The second area is related to the procedures that are employed to assess student performances. The third area is related to the limited and the inconsistent use of reinforcement.

Performance Monitoring. Performance monitoring consists of the practice employed by a teacher or contingency manager to observe student performances. With traditional or new curricular chemistry programs, the performance monitoring method most often employed consists of the teacher asking questions in a class or group setting. Within class

settings, the opportunity for each student to respond orally to each question that is asked is not usually possible. The teacher can monitor only the performances of students who individually volunteer or those to whom a question is directed. The teacher has no method to simultaneously monitor the oral performances of the remaining students in the class on each question asked. With the use of the individualized instructional packages, the teacher can monitor both oral and written performances of each student on an individual basis. The student must first present himself to the teacher who in turn can direct questions that are specifically related to some objectives in the package. This is an effective monitoring practice except that as the number of students working through such packages increases, the time available to the teacher to monitor the varied performances of each student decreases.

Performance monitoring however has not been limited to individual oral responses in group settings or with individual performances as is found with the use of instructional packages. Recently, two direct performance monitoring systems have been developed by Wyman, (1968a, 1970). These systems combine the benefits of individual performance monitoring but in a group setting. The first system is electro-optically based and the second is an electronic modification over the first. With these systems, a teacher can observe a wide range of constructed student performances and not be

limited to response systems involving multiple choice type items. The electro-optical system is referred to as the MIVR (Mediated Interaction Visual Response) system. The electronic system is referred to as the MITVR (Mediated Interaction Television Visual Response) system. A primary function of both these systems is to be able to monitor performances of several students simultaneously through visual observation of the performances as they are emitted.

Wyman (1969a) in discussing the MIVR system, indicated how a teacher could observe the performances of a group of students as they construct responses to questions that are presented to them. This observation occurs by having an image of the constructed response projected onto a screen located behind the student. Wyman (1969a) described some of the characteristics and benefits of the MIVR system by stating:

The visual response system ... provides the teacher with a visual mode of presenting material through his overhead projector and other projectors at the back of the room. It provides each of eight students with a means of visual communication to the teacher and the other students through his own overhead projector. With a sheet of acetate on each student's projector, the teacher can request that all students write or spell a word, write the verb in a sentence presented on the teacher's overhead, identify a

bird from the filmstrip projector, write a sentence describing the action from the movie projector, solve problems from the overhead, etc. With eight student transparencies of a diagram, maps, problems from the overhead, etc. all students can simultaneously color, underline, point to, solve, choose appropriately, etc. as the teacher teaches and requires regular responses. The teacher turns on the student overheads at selected and frequent intervals to scan all responses and comment on them as desired.

Immediate reinforcement of acceptable response is provided as in programmed learning, and mistakes are immediately identified and corrected. The usual learning of mistakes that are corrected much later is avoided.

The MIVR system has been successfully utilized for direct performance monitoring by Eachus (1969a) and by Piper (1970). These investigators employed the MIVR system in schools for the deaf and were able to monitor complex student performances which would have been difficult if not impossible under prior conditions. Utz (1970), conducted a field investigation of the MIVR system in a school for the deaf and found that the number of observable emitted student responses increased with the use of the system.

Performance monitoring is a major component in the learning process and both the MIVR and MITVR systems are capable of increasing the frequency of observable responses emitted by students. The MIVR and MITVR systems have not been employed in public schools or in the area of chemistry.

Performance Assessment. Performance assessment consists of the procedures employed by teachers, contingency managers and others to determine the extent of a student's repertoire during a performance monitoring event. Within a class or group setting, the performance monitoring event sets the occasion for performance assessment. If a student orally responds to a question, the response is matched against what the teacher considers to be an acceptable response and what was emitted by the student. If a match occurs, the assessment of the performance for the student is complete. As with performance monitoring, the opportunity to assess individual performance of each student on a daily basis is limited to the number of performance monitoring events which can occur. Performance assessment however is not limited to single oral responses in a class or group setting. A procedure often employed by teachers is the administration of a quiz, test or some instrument which may contain a variety of items that are designed to sample the students' repertoires. Skinner (1968a) suggests that under the exigencies of such tests and testing events, the performances which are sampled do not adequately reflect student

performances.

A problem which arises as a result of employing instruments is that students do not have immediate knowledge of their performance and often must wait until all the instruments are corrected and returned. Skinner (1968b) comments on the effects of delayed knowledge of performance:

It can be easily demonstrated that, unless explicit mediating behavior has been set up the lapse of only a few seconds between response and reinforcement destroys most of the effect.

In a typical classroom, nevertheless, long periods of time customarily elapse.

When instruments are returned and the class on the average is judged to have done satisfactory work by the teacher, the class normally will proceed to the next unit or chapter of work. If the performance of the class on the average is judged to be unsatisfactory then the teacher can elect to review and reassess the weak areas. Often however, the simpler expedient of deemphasizing the poor group performance is employed by using such techniques as scaling.

With the use of individualized instructional packages, performance assessment occurs whenever a student presents himself for assessment. Two procedures are generally employed. The first consists of a series of questions by the teacher to sample the student's repertoire. The second involves the use of written instruments. With the former procedure, the

student responds to questions which may be random selected from and related to the specific objectives of the package. If the emitted responses are unsatisfactory in this assessment event, the student is normally permitted to take a more formal written instrument to assess his performance. If the performance on a particular item is unsatisfactory, the teacher can either prompt the desired response or prescribe some remedial instructional activity to overcome the unsatisfactory performance. If remediation results in a prescription, another assessment event will have to occur for that student before he is permitted to continue with the package or permitted to take a written instrument. The recycling which results from prescription may result in a substantial period of lost time for the student. In some cases his grade may also be affected by this needed extra time, (Bethune 1967b). The recycling and reassessment of a student also results in an added encumbrance on the total time available for the teacher to monitor, assess, diagnose, remediate and then prescribe some instructional alternative to that student and to other students. The consequences are easily compounded and a serious queing problem can develop as the number of monitoring events in the curriculum and the number of students requiring remediation and recycling increases. DeRose (1970b) observed that his was a serious problem even with a class of nineteen chemistry students.

The problems associated with student performance assessment in teaching high school chemistry are many and they are complex. In a group or class setting, there are limitations due to the number of individual performance monitoring events which are possible. If performance assessment involves the use of instruments such as tests, the instrument may not adequately sample the individual's repertoire and the circumstances related to the testing event may also affect the performance of students.

Reinforcement. Reinforcement is the application of salient and desirable consequences contingent upon the emission of desired performances or behaviors. According to Skinner (1968c), it is the critical condition in the process of learning:

Learning does not occur because behavior has been primed; it occurs because behavior primed or not, is reinforced.

Skinner further comments on the use of reinforcement in classrooms.

Perhaps the most serious criticism of the current classroom is the relative infrequency of reinforcement.

Forness (1968) further adds to Skinner's position by stating that although there are a number of reinforcers that teachers can use daily in the classroom,

The misfortune of children and teachers alike is that these reinforcers are seldom used systematically and their effectiveness is thereby missing.

For learning to occur, performances must be monitored, assessed and then reinforcing stimuli applied in accordance with some schedule that is effective.

The application of reinforcers has had an extensive history of development which is traceable through the field of experimental analysis of behavior to Skinner's work with infra-human organisms. His work has suggested the application of behavior modification principles to constructing the conditions and consequative events for human performances in clinical and naturalistic settings.

The stimulus events available to chemistry teachers which serve as consequences for desired emitted performances have generally included the use of praise, attention and other such social reinforcers. Another category of reinforcers is the use of points leading to grades.

Grades and social reinforcers are employed by chemistry teachers in the classroom setting and also with the use of individualized instructional packages. In the classroom setting, social reinforcers are applied contingent upon the emission of desired performances of individual students. The frequency of and the opportunity for applying these reinforcers is directly related to the number of monitoring events

possible within a given time period. In the classroom, social reinforcers are applied as students emit desired responses. With the use of individualized instructional packages, reinforcers are applied by the teacher contingent upon the emission of desired performances by students. If the emitted performance is a match with a performance that is judged acceptable, the performance is consequted. With the use of instructional packages, consequtation can be more frequent and can be more consistent. The frequency however is limited to the number of assessment events possible and the number of teachers or contingency managers that are available.

Consistency in application of consequences is limited in traditional classrooms and in those settings which employ individualized instructional packages. A major limitation is due to the lack of knowledge on the cumulative effects that specific types of consequences have had for each student, (Skinner 1968d). Seldom is a teacher provided with this ontogenetic information so that effective schedules of reinforcement can be applied.

Successive Approximation. The modification and control of behavior results from applying reinforcers contingent upon desired emitted performances. The process of shaping is available if a desired performance cannot be emitted by a student. The process involves reinforcing successive approximations leading to the desired performance. In order to manage such a process, the successive approximation performances

must be monitored, assessed and then consequated. The process has been extensively employed with infra-human organisms and the principles have been applied in the development of programmed instructional materials. In discussing the successive approximation process which leads to the acquisition of complex performances, Skinner (1963a) stated:

A complex topography can be 'shaped' with a series of changing contingencies called a program, each stage of which evokes a response and also prepares the organism to respond at a later stage.

There are many complex performances associated with the learning of chemistry. These complex performances are often referred to as problem solving. Skinner (1963b) comments on problem solving and states:

Complex terminal contingencies involving multiple stimuli and responses, in sequential or concurrent arrangements, are often called problems. An organism is said to have solved such a problem when it comes under the control of terminal contingencies. Its capacity to respond appropriately under such contingencies must, however, be distinguished from its capacity to reach them through a given series of intervening stages.

Within the classroom, successive approximation practices cannot normally be administered by teachers or contingency managers because of the large number of monitoring, assessing and consequative events that are involved in complex performance acquisition. Teachers, however, can be in a position to recommend instructional materials and even prescribe programmed materials when the materials are applicable and available and when the teacher feels that they would be appropriate for the student.

Successive Approximation and Contingency Management.

The experimental analysis of behavior has concentrated upon the examination of performances emitted by single organisms. With the use of successive approximation in performance acquisition, reinforcement is applied as approximations toward some criterion performance are emitted by the organism. Contingency management is the control of reinforcers that are applied in the process of successive approximation. Contingency management however, is not limited to shaping. According to Homme, (1968):

Contingency management is the management of what events are contingent upon what behavior. It is clear that contingency management is merely the taking seriously (literally) that great law of life: When reinforcing events are contingent upon a given behavior, the behavior will increase in strength; when they are not the behavior will decrease in strength ...

One can make a pretty good case that, basically there are only two things that a good contingency manager has to know and do: (a) to reinforce the behavior he wants, and (b) to recognize and reinforce approximations to this behavior.

Homme's description suggests that contingency management can be interpreted both narrowly in the case of successive approximation and also more widely to include the control and management of what events are contingent upon what behavior. It is the latter meaning that is employed in this investigation.

Problem. This investigation is concerned with evaluating a system of teaching high school chemistry by the use of contingency management. The modification and maintenance of behavior through systematic analysis of contingencies has been widely investigated in a number of different settings. These settings have been generally classified as experimental, clinical, special, and educational. Within educational settings most investigations have analyzed disruptive behaviors and mal-adaptive behaviors in classrooms. Limited behavioral research has been conducted at the public elementary and secondary levels in academic or subject content areas.

Knowles (1969) reported the results of nineteen studies in which successful results were obtained in modifying disruptive behaviors and non-learning behaviors with selected elementary and junior high school students.

Martin (1970) conducted an extensive review of over one hundred studies of "Behavioral Research Relevant to the Classroom". It was observed that the majority of the studies reviewed were focused on target behaviors of students who were hyperactive, behavioral problems, and also complex target behaviors such as speech pathology and reading difficulties. No studies were reported by Martin in the area of science education.

Only one study conducted, Nesselroad (1970a) was found that was related to science education. Nesselroad investigated the effect of using points which were exchangeable for grades as a reinforcer for study behavior. Four broad study behaviors were recorded on a rating sheet. The study behaviors included talking to peers, talking to teacher or group, out of seat learning and working at assigned material at a desk. Two non-study behaviors were also recorded and a ratio of study to non-study behaviors was computed and served as the basis for giving points leading to grades.

The study behavior of twelve randomly selected students was investigated. The students were selected from a tenth grade biology class of thirty three students. The investigation required the presence of four additional personnel in the class along with the regular teacher. Two individuals were employed to monitor and assess the study behavior of twelve students and the other two were used to deliver the reinforcers to the students. The investigation was conducted over a period of sixteen days and the results indicated that

the study behavior of seven out of the twelve students improved. Five students did not show any improvement and Nesselroad (1970b) commented on these by stating:

The predicted pattern of increased studying during contingent point-giving (periods II and IV) occurred in seven out of twelve students. (The probability of seven out of twelve individuals having one pattern by chance is .0002.) Two of the remaining students (numbers 6 and 10) had such a high initial study percentage that improvement would have been difficult. Still the giving of points seemed not to influence the behavior of some students.

In her conclusion, Nesselroad (1970c) stated:

The problem of motivating desirable behavior lies in establishing contingencies. For maximum effectiveness, reinforcement must be frequent and must immediately follow the desirable behaviors. In the present study, frequency was accomplished through the addition of extra personnel, a resource not available to most teachers. In addition, the specific behaviors to be rewarded were not specified precisely enough; the aides reported that they could not distinguish studying and daydreaming if a student was facing his book.

Nesselroad points to some of the limitations of her study by indicating the increased number of personnel that were required for performance monitoring, performance assessment and to deliver reinforcers. It is also clear that one category of behaviors may have confounded the results of Nesselroad's investigation since the ratio of study to non-study behavior included the category in which the aides could not distinguish between study behavior and daydreaming.

No studies were found in the literature in which contingency management principles had been applied to the teaching of high school chemistry.

In order to overcome some of the limitations associated with earlier investigations, a technology of teaching needed to be established. The technology required the employment of contingency management procedures. The contingency management procedures required the specification of performance objectives, the arrangement of an environment in which the performances could be monitored and assessed and the ability to immediately apply salient and desirable consequences contingent upon the emission of desired performances. The problem this study addressed itself to was to develop and assess such a technology.

C H A P T E R II

METHOD

Subjects. The investigation was conducted in a middle class suburban community, South Hadley, Massachusetts. A single high school containing grades 9 - 12 with about 1200 students was the site of the investigation. The experimenter was employed by the school system as an instructor in Chem Study Chemistry. An initial request was made by the experimenter to limit the size of one Chem Study class to twelve students. This request could not be accommodated because of scheduling conflicts with other courses. Sixteen students were scheduled for the course. Two students requested a transfer to another chemistry course. The data for one student was not reported because of extremely high absenteeism during experimental phases I and II of the investigation. Data was collected for the remaining thirteen students during each of the four experimental phases of the study. Of the thirteen students, eleven were juniors (grade 11) and two were seniors (grade 12). Academic standing and other data are listed in Table 1.

The administrative schedule that was employed can be described as a rotating seven period traditional block of forty-four minutes with a fixed schedule for laboratory days. Wednesdays were scheduled as double periods for laboratory

The experimenter possessed an undergraduate major in chemistry (1966) and had taught (without formal NSF training) the course for a period of three years. The year prior to conducting the study, the experimenter was on leave of absence from the school system.

Design Considerations. The design employed in this investigation was typical of those employed in behavior modification studies. In behavior modification studies, the independent variable is applied after a period of Baseline determination. The independent variable is manipulated for each single subject who served as his own control. Reliability is established through reversal and then reinstatement of the independent variable. The design therefore differs from those in which the experimental variable is applied across a group of students with a second group serving as the control to test the effect of the treatment.

Eachus (1969b), commented on the former type of design and stated:

The design ... is more similar to the single subject multiple manipulation, multiple replication than it is to the multiple subject, single manipulation single replication type.

Four experimental phases were conducted in the design employed in this investigation. Phase I was a period of Baseline determination. Phase II was a period of Instatement of the Reinforcing Contingency. Phase III was a period of

Reversal. Phase IV was a period of Reinstatement of the Reinforcing Contingency.

Limitations of Investigation. There were several limitations associated with the investigation. The first limitation was that the investigation measured only the effects of consequating performances during experimental sessions and did not attempt to measure the effects that such consequations had on long term retention of performances by the students.

A second limitation was that the students involved in the investigation can individually and collectively be categorized as above average. The students are probably also not representative of the general student population in number of other ways.

A third limitation of this investigation was the responses emitted by the students were limited to the performance objectives listed in appendix 2.

Experimental Objective. The experimental objective in this investigation was to determine the effect that a system of teaching which employed a contingency management procedure had on the attainment of desired performances in high school chemistry. The procedure used was to consequate emitted performances which were judged accurate. Consequation occurred only during the second and fourth experimental phases. During the first and third experimental phases accurate performances were not consequated. Explicit statements of the reinforce-

T A B L E I

BACKGROUND DATA ON SUBJECTS

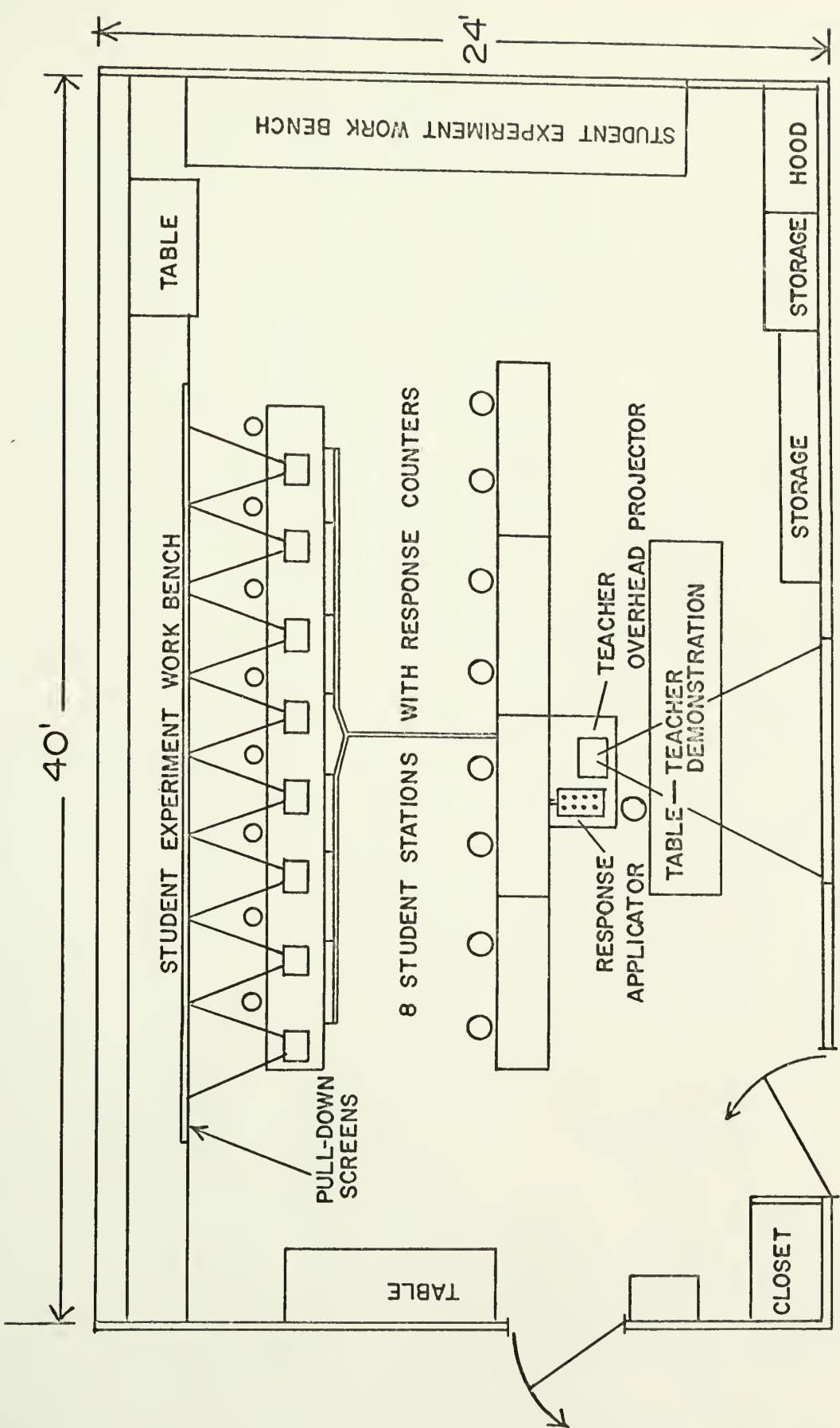
Subject #	Age at onset of study	Sex	I. Q. Otis Gamma	Ranking of student in previ- ously completed year
1	16 yrs 5 mo	Male	130	47 / 306 Soph class
2	16 yrs 8 mo	Male	112	94 / 306 Soph class
3	15 yrs 9 mo	Female	132	12 / 306 Soph class
4	16 yrs 5 mo	Male	121	30 / 306 Soph class
5	15 yrs 7 mo	Male	115	42 / 306 Soph class
6	15 yrs 11 mo	Female	131	13 / 306 Soph class
7	16 yrs 5 mo	Male	126	23 / 306 Soph class
8	16 yrs 11 mo	Female	116	16 / 278 Junior class
9	15 yrs 6 mo	Male	119	35 / 306 Soph class
10	16 yrs 8 mo	Male	130	1 / 306 Soph class
11	16 yrs 4 mo	Male	120	93 / 306 Soph class
12	16 yrs 0 mo	Male	125	47 / 306 Soph class
13	17 yrs 2 mo	Female	118	8 / 278 Junior class

ment contingency were read to students at the beginning of phases two and four.

The independent variable was the application of a reinforcement contingency during phases two and four of the investigation. The dependent variable was the percentage of responses emitted by each student which were judged to be acceptable during each experimental phase. A second dependent variable, the percentage correct of items each student attempted was also measured.

Equipment. Performance monitoring was accomplished through the use of a Mediated Interaction Visual Response System, (MIVR). The MIVR system was developed by Wyman (1968b) and permits a teacher or contingency manager to monitor student performances as they are constructed and emitted. A traditional chemistry classroom in the high school was equipped with an eight station MIVR system, see room diagram Figure 1. Each station was equipped with an electro-mechanical response counter. Each station was also equipped with a pull down screen that could easily be raised when the students were conducting laboratory experiments.

Procedure. The Chem Study course did not include specific performance objectives as part of the teacher's guide. The first problem was to prepare lists of performance objectives sufficient for the duration of the investigation. Performance objectives were related to content material in the Chem Study textbook and also related to similar content in a supplementary textbook (Foundations of Chemistry, Holt,



SCALE: 1" = 5'

FIGURE 1. MODIFICATION OF CHEMISTRY LABORATORY FOR MIVR SYSTEM.

Rinehart and Winston, 1969).

Thirty-five lists of performance objectives were prepared, see appendix 2. Students were given a single list of objectives at a time and also were given either verbal or written directions which specified the instructional activities that were related to the objectives. Instructional activities included having the students conduct homework assignments such as reading from the texts, solving recommended types of problems, conducting laboratory experiments, making observations during class demonstrations and taking notes during class presentations. Except for laboratory reports, students were not required to turn in any written homework. The day following the completion of the instructional activities, a performance monitoring and assessment session was scheduled. During these sessions the students constructed responses to items related to the performance objectives they had been given.

On the days scheduled for performance assessment, seven students were seated at the MIVR stations and six were seated at positions in front of the class. The seven students seated at MIVR stations constructed responses on transparency material and these responses were projected on a screen behind them. The six students seated in front of the class constructed responses on paper. The seven students seated at MIVR stations rotated with the six seated in front of the class on alternating sessions. During the second and fourth

experimental phases, a reinforcement contingency was employed.

Phases of Investigation. There were four experimental phases in the investigation. Phase I was a period of Baseline determination. Phase II was a period of Instatement of Reinforcement Contingency. Phase III was a period of Reversal to Phase I conditions. Phase IV was a period of return to Phase II conditions.

Baseline, Phase I. Students were given the following directions at the beginning of Baseline. "You will be given lists of performance objectives for the course material as it is covered. The day after you complete the instructional activities related to the objectives, a performance assessment session will be conducted. During the performance assessment session you will construct responses to items that are related to the objectives you had been given." No mention was made as to how the results of these sessions would be related to grades.

During this phase of the study, students constructed responses to items when seated either at MIVR stations or in front of the class. All students worked independently and those seated at MIVR stations were directed to keep their projectors on.

The experimenter sat at the front of the class after passing out the materials. Every attempt was made by the

experimenter not to pay differential attention to any one student or to the constructed response images which were projected on the screens. No attempt was made to indicate to the students the accuracy of their emitted responses. The response materials were collected when it appeared that students had sufficient time to attempt the items and that further time would not produce improvement. This was a subjective judgment that had to be applied at each experimental session during each of the four phases since no previous studies were uncovered which helped to solve the time problem. A first approximation to the expected time required by the students for each experimental session was made by the experimenter when he measured the time required for him to construct responses to the items that were prepared. It was then estimated that the session times would range from one and one half to two times the measured response time required by the experimenter.

Criteria for Baseline Termination. The organizational outline of the Chem Study course was generally followed in this investigation. At the beginning of the Chem Study course a student normally conducts a series of laboratory experiments. The first six sets of performance objectives were therefore related to laboratory instructional activities. The seventh through eleventh sets of objectives were related to non-laboratory instructional activities. Since the transition from laboratory to non-laboratory instructional activ-

ities was unknown in terms of its effect on the accuracy of emitted responses by students, it was decided to observe the average performance of each student under these two conditions and set up an instatement criterion on the observed difference.

The criterion for terminating Baseline and Instating the Reinforcement Contingency was to be met when ten students exhibited no more than a twenty percent difference in the accuracy of their emitted performances for items related to laboratory and non-laboratory instructional activities. At the end of the tenth session, ten of the thirteen students had met the instatement criterion and Baseline was terminated.

Instatement of Reinforcement Contingency, Phase II.

The day following the completion of session number ten, students were advised of the grading procedure that would be employed and the next set of performance objectives was given to them. Students were read the following directions on the day scheduled for performance monitoring and assessment. "You are to construct responses to the items that are on the transparency and paper materials like you have been doing. For students seated at projectors, you are to signal me each time you complete any item of your selection. Signal me by turning off and on your projector to gain my attention and when you gain my attention, point to the item you have completed and want checked. If the response is accurate, I will give you a point that will be registered at the response counter in front of you. If the item is not accurate, I will shake my head in a negative manner and you may attempt the item again or go on.

The points you acquire will be used to determine your grade for the course as outlined to you earlier. Students not seated at overhead projectors will be able to obtain information on their performance by coming in and observing the posted information on the bulletin board."

During this phase of the investigation, each accurate performance emitted by students seated at MIVR stations was immediately monitored, assessed and consequated. No attempt was made to provide differential attention such as smiling or providing verbal praise when the performances were consequated. Except for the negative head motion, every attempt was made not to indicate displeasure or dissatisfaction when a response was not accurate and could not be consequated. Cueing or prompting was not used. At the end of the sessions, the materials were collected and the percentage of accurate responses out of the total possible was calculated for each student. The percentage results were posted on a bulletin board in the experimental room within an hour after the session was completed.

So that the content material would not be rapidly changing as is often found when proceeding from one chapter in a text to another, a criterion for termination of Phase II conditions was set up if the experimental effect was observed for Phase II conditions. The criterion for terminating phase II and reversing to Phase I Baseline conditions was to occur only within an ongoing set of content within a chapter. At the end of the twenty-second session, the termination criterion was met.

Reversal, Phase III. During this phase of the investigation conditions were returned to Baseline status. Students were read the following statement. "From now on I will not be checking each of your responses and giving you points if they are correct. Complete the items as best you can." The experimenter passed out materials as usual but did not make any attempt to indicate to the students the accuracy of their emitted responses. No results were posted on the bulletin board. Every effort was made by the experimenter not to pay differential attention to any one student or to the constructed response images which were projected on the screens. The response materials were collected when it appeared that students had sufficient time to attempt items and that further time would not produce improvement.

A criterion for terminating Reversal phase was also employed for reasons similar to the criterion for terminating Phase II. The criterion for terminating Phase III and reinstating the reinforcement contingency was to occur only within an ongoing set of content within a chapter. At the end of the twenty-eighth session the criterion was met.

Reinstatement, Phase IV. During this phase of the investigation, Phase II conditions were reinstated. Students were read the same statement as was read in phase II. Accurate responses were consequted with points as in phase II. The grading criteria that was employed in phase II was also employed in this phase.

Grades. Grades were the reinforcer most readily avail-

able and manipulable. In order to obtain permission to conduct the study, it was agreed that the grading policy of the school would not be changed and that letter grades be issued. Since the investigation involved the manipulation of this reinforcer during experimental phases and since the students would not be receiving points leading to grades for the first and third experimental phases, a violation in policy could occur if letter grade progress or marking reports had to be issued during these phases. To overcome this problem it was decided to have each student's letter grade made up of a part that was fixed and a part that was manipulable. The fixed part was based on the results on laboratory reports and periodic tests. The manipulable part was based upon a student's emitted performance during the experimental sessions. By setting up the grading procedure in this way, the experimenter could always provide a letter grade on the fixed part to satisfy school policy. Students were not given explicit statements of how their grade would be determined except at the beginning of phases II and IV.

At the beginning of phases II and IV the students were told that seventy percent of their overall grade would be based upon the accurate responses to items related to the performance objectives they were given.

To receive an A for the emitted responses, a student would have to acquire 86% or better for the total number of items possible.

To receive a B for the emitted responses, a student

would have to acquire between 81 - 85% of the total number of items possible.

To receive a C for the emitted responses, a student would have to acquire between 75 - 80% of the total number of items possible.

Any student who received less than 75% of the total number of items possible and who also did not show any systematic improvement, would become a candidate for invoking alternative contingencies. Students were not told that if they performed at this level they would become candidates for alternative contingencies.

In addition to the stated letter grading criteria, a bonus condition was also given to the students. Students were told that if their performance improved systematically, (during phases II and IV), they would receive the next letter grade higher at marking time. They were also told however, that if their performance decreased systematically, (during phases II and IV), they would receive the next letter grade lower. Determination of what constituted a systematic decrease or improvement of performance was not specified to the students and was to be based upon the experimenter's graphed information of student performance data.

CHAPTER III

RESULTS OF INVESTIGATION

Results will be presented in subsections for the group and also for each individual student. Observations are directed toward the percent correct of total items possible and the percent correct of the items attempted. Graphs of performance data are presented in figures 2 through 15. Data points on graphs are represented as dotted circles for the percent correct of total items possible and triangles for the percent correct of total items each student attempted. Attention is directed to the sessions where a triangle is above a circle. During these sessions the students did not attempt all the items possible but attained a higher percent correct on the items they attempted. Coincidence of a circle and a triangle indicated that the students attempted all items possible and the percent correct is as indicated. Use of the term accuracy will be restricted to describing results on the percent correct of total items possible. Table II represents the means for the group and for each individual student on the percent correct of total items possible and the percent correct for the total items attempted during each experimental phase.

Group Results. The results for students as a group were obtained by taking the average performance for all students

during each experimental session in each of the four phases.

Data on Table II list the means for the percent correct of total items possible and the percent correct of total items attempted for each student and for the students as a group during each of the four experimental phases of the investigation. The mean performance for all students on the percent correct of items possible was 60% for phase I, 85% for phase II, 36% for phase III and 89% for phase IV. The mean for students as a group on the percent correct of items attempted was 62% for phase I, 92% for phase II, 41% for phase III and 89% for phase IV. Attention is directed to the performance of students and the group during phases I and III. The performance levels for each individual and for the group during phase III was lower than the performance level during phase I on both the percent correct of items possible and the percent correct of items attempted. A decrease of 24% below Baseline level was observed for the performance of the group on the percent correct of total items possible during phase III. A decrease of 21% below Baseline level was observed for the performance of the group on the percent correct of total items attempted during phase III.

The criterion for terminating Baseline conditions and instating the Contingency of reinforcement was to occur when ten of the thirteen students had a performance difference no greater than twenty percent for the first six sessions compared with the sessions following number 6. Attention is directed to subjects 2, 6 and 13 who did not meet the instatement criterion.

T A B L E II

PERFORMANCE MEANS

⊙ = Mean Percent Correct of Total Items Possible

△ = Mean Percent Correct of Items Attempted

	I		II		III		IV	
	⊙	△	⊙	△	⊙	△	⊙	△
S ₁	52	56	80	86	28	32	75	75
S ₂	67	73	95	96	40	56	93	93
S ₃	51	56	82	90	29	30	75	76
S ₄	57	62	94	97	41	45	99	99
S ₅	59	70	90	93	35	46	93	93
S ₆	65	71	86	93	40	54	93	93
S ₇	56	60	86	93	39	46	94	94
S ₈	63	66	82	91	30	33	90	90
S ₉	55	66	78	91	30	36	71	65
S ₁₀	52	66	83	94	33	42	92	92
S ₁₁	71	77	78	94	34	42	94	94
S ₁₂	57	63	83	88	37	41	90	90
S ₁₃	68	72	92	96	53	58	96	96
Group	60	62	85	92	36	41	89	89

These three students had individual performance means during phases I, II, III and IV on both the percent correct of items possible and the percent correct of items attempted which were above the means of the students taken as a group. Attention is also directed that these three students also attained the highest three means during phase III on the percent correct of items attempted.

Figure 2 represents a graph of performance data for the group.

Phase I (Baseline) was in force for sessions 1 - 10. Accurately emitted responses to items presented were not consequated during this phase. Subjects 3, 5 and 12 were absent for session 3. Subjects 3, 5, 7 and 12 were absent for session 4. Subjects 6, 10 and 11 were absent session 5. Subject 13 was absent session 6 and subject 2 for session 9. Performance during Baseline was unstable for the group and ranged from 44 to 83% correct for the total items possible. During session six, seven and ten, the percent correct of items the students attempted was higher than the percent correct of total items possible. During phase I the mean for all students in the group on the percent correct for total items possible was 60%. The mean for all students in the group on the percent correct of total items attempted was 62%.

Phase II (Instatement of Reinforcement Contingency), began with session 11 and ended with session 22. Subject 9 was absent session 16 and subject 12 on sessions 13 and 14.

Commencing with session 11, a systematic increase in the percent correct of total items possible was observed. Performance was stable compared with Baseline and ranged from 72 to 95% correct. The percent correct on the total items attempted increased rapidly and a fairly stable level of performance ranging from 76 to 98% occurred after session 11. The mean for all students on the percent correct of total items possible increased from a Baseline level of 60% to 85%. The mean for all students on the percent correct of total items attempted increased from a Baseline level of 62% to 92% correct.

Phase III (Reversal) was initiated with session 23 and terminated on session 28. No consequence of emitted performances was conducted during this phase. Subject 6 was absent session 25, subject 7 on session 27, subject 8 on sessions 27 and 28, subject 11 on sessions 26 and 28 and subject 13 on session 28. Performance for the group during Reversal was unstable, similar to Baseline, and the range on the percent correct of total items attempted was from 24 to 60%. This represents only a three percent difference between the range of instability compared with Baseline. The mean for all students in the group on the percent correct for total items possible was 36% and this value represents a decrease of 24% compared with Baseline performance and a decrease of 49% compared with phase II. The mean for all students in the group on the percent correct of total items they attempted was 41% and this value represents a decrease of 21% compared with

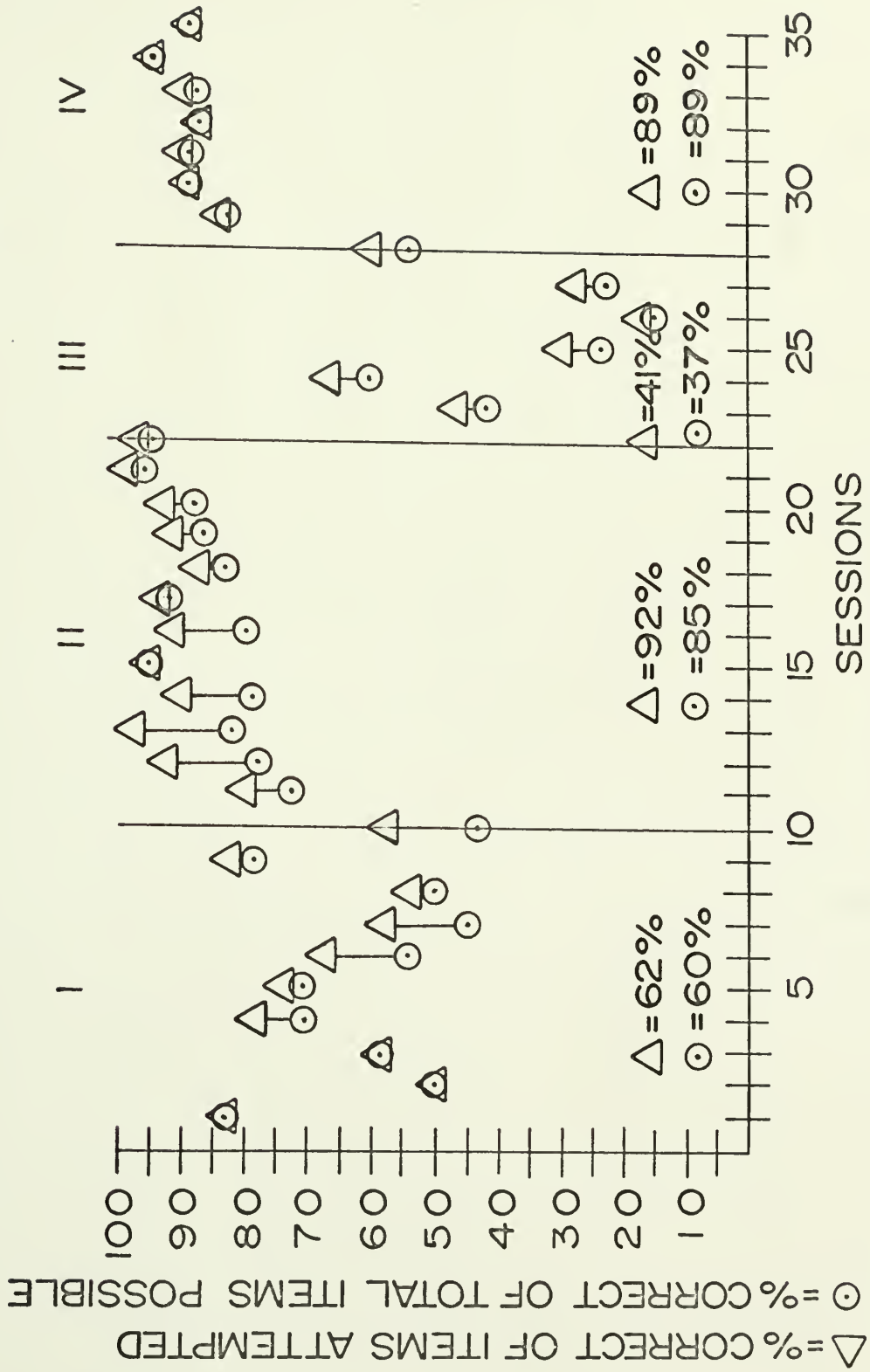


FIGURE 2. GROUP

Baseline data and a decrease of 51% compared with phase II. Phase II, Reversal, was marked with negative student reaction from the beginning. On one occasion prior to session 23 a delegation of students approached the investigator to have him reconsider the giving of points. The delegation seemed to reflect the position of all the students in the group.

Phase IV (Reinstatement of Reinforcement Contingency) began with session 29 and ended with session 35. Consequence of emitted items judged accurate was reinstated. Subject 1 was absent session 29, subject 9 was absent session 31, subject 10 was absent session 33 and subject 11 was absent session 30. Performance for the group during phase III, Reinstatement, was stable and ranged from 83 to 96% correct on the total items possible. A slight increase in accuracy across the sessions in this phase was observed but not as apparent as in phase II. The mean percent correct of total items possible for the group was 89%. This value represented an increase of 4% compared with phase II. The mean percent correct of total items attempted by the students was 89% and this value represents a decrease of 3% compared with phase II. When the announcement was made that point application would be reinstated, the students spontaneously expressed signs of happiness such as cheering, clapping and shaking each other's hands.

Table III presents data for the group and for each student.

The table presents data related to the effects of applying reinforcement directly through the MIVR system as opposed to delaying knowledge of results by one hour until after the class was over. Because of the limited physical size of the classroom, students rotated from the MIVR system to the student desks in front of the projectors. The data indicate that the accuracy of responding was consistently higher for almost all students when they were employing the MIVR system and constructing responses which could be observed instantaneously. Unfortunately, the individual data by sessions for each subject on the use of the MIVR was lost in part although the overall data was retained for the entire phase.

During phase I students who were seated at the MIVR stations attained 62% correct of total items possible as opposed to 59% for those not on. During phase II, Instatement of Reinforcement Contingency, students seated at the MIVR stations attained an accuracy of 87% compared with 81% for those who were not seated at MIVR stations. During phase III students seated at MIVR stations attained 37% correct as opposed to 38% for those not on. During phase IV students at MIVR stations attained an accuracy of 94% compared to 84% for those not seated at the MIVR stations.

Individual Results. Subject 1 (S_1) was absent for session 30. The mean percent correct of total items possible was 52%

T A B L E I I I

MEAN STUDENT PERFORMANCE ON AND OFF THE MIVR

Subject	Phase I		Phase II		Phase III		Phase IV	
	%On	%Off	%On	%Off	%On	%Off	%On	%Off
S ₁	53	58	88	77	39	17	80	72
S ₂	71	62	92	97	47	32	92	94
S ₃	46	60	77	73	33	50	90	64
S ₄	50	63	95	93	29	55	100	98
S ₅	51	65	91	88	45	26	97	86
S ₆	72	60	88	83	56	49	100	88
S ₇	60	50	86	84	41	38	96	91
S ₈	53	72	86	76	35	25	95	86
S ₉	50	62	83	70	24	37	80	51
S ₁₀	60	44	80	79	28	37	97	87
S ₁₁	80	63	79	71	35	32	100	93
S ₁₂	74	40	86	72	31	43	94	97
S ₁₃	72	62	96	84	37	76	94	97
Group	62	59	87	81	37	38	94	84

for phase I, 80% for phase II, 28% for phase III and 75% for phase IV (Fig. 3). The mean percent correct of items attempted was 56% for phase I, 86% for phase II, 32% for phase III and 75% for phase IV. During phase I, Baseline, the performance was unstable and ranged from 14 to 88%. During sessions 9 and 10 of Baseline, S₁ attained a higher percent correct on the items she attempted compared with other sessions of that phase. Following Baseline, the accuracy on the mean percent correct for total items possible increased from 52% to 80% in phase II. During phase II (Instatement of Reinforcement Contingency) S₁ showed a rapid increase in performance accuracy. In session 12 she attempted fewer items but attained a higher percent correct on the items attempted. During session 16, S₁ appeared pale and approached the investigator at the end of the session to indicate that she was not feeling well. With the exception of session 11, 12 and 16 the performances during phase II were stable and ranged from 83 to 100%. With the onset of phase III (Reversal) a decrease in accuracy to 28% occurred and this was a drop of 24% below Baseline accuracy. An unstable pattern of performances also occurred during phase III with accuracy ranging from 6 to 62%. During session 23 of phase III an increase in percent correct of items attempted was observed. During phase IV (Reinstatement of Reinforcement Contingency) accuracy rose to 75% reflecting an increase of 47% over Reversal and a 5% decrease over phase II. Observation of the pattern of performances during phase IV indicates a clear rising trend of increased accuracy. Subject 1 received

a B for phases II and IV.

Subject 2 (S_2) was absent session 9. The mean percent correct of total items possible was 67% for phase I, 95% for phase II, 40% for phase III and 93% for phase IV (Fig. 4). The mean percent correct of items attempted was 73% for phase I, 96% for phase II, 56% for phase III and 93% for phase IV. Starting with session 2 of Baseline and continuing to session 6 a systematic increase in performance accuracy was observed. A reversal occurred with session 7 followed by another increase in performance accuracy to session 10. Response items in sessions 1 - 6 were related to laboratory instructional activities, items from sessions 7 - 10 were related to non-laboratory instructional activities. The criterion for terminating Baseline and Instating phase II was that ten of the thirteen students would have no more than a twenty percent difference between the average performance on items related to laboratory activities, sessions 1 - 6, compared with the performance on items related to non-laboratory activities which occur from session 7 on. S_2 was 12% above the instatement criterion and was one of three students who did not meet it.

During phase II (Instatement of Reinforcement Contingency) S_2 showed a systematic high degree of accuracy with a mean of 95% for the phase. Beginning with phase III (Reversal), S_2 showed a rapid decrease in performance accuracy. The mean for phase III on the percent correct of total items possible was 40% and this reflects a decrease of 27% compared with the per-

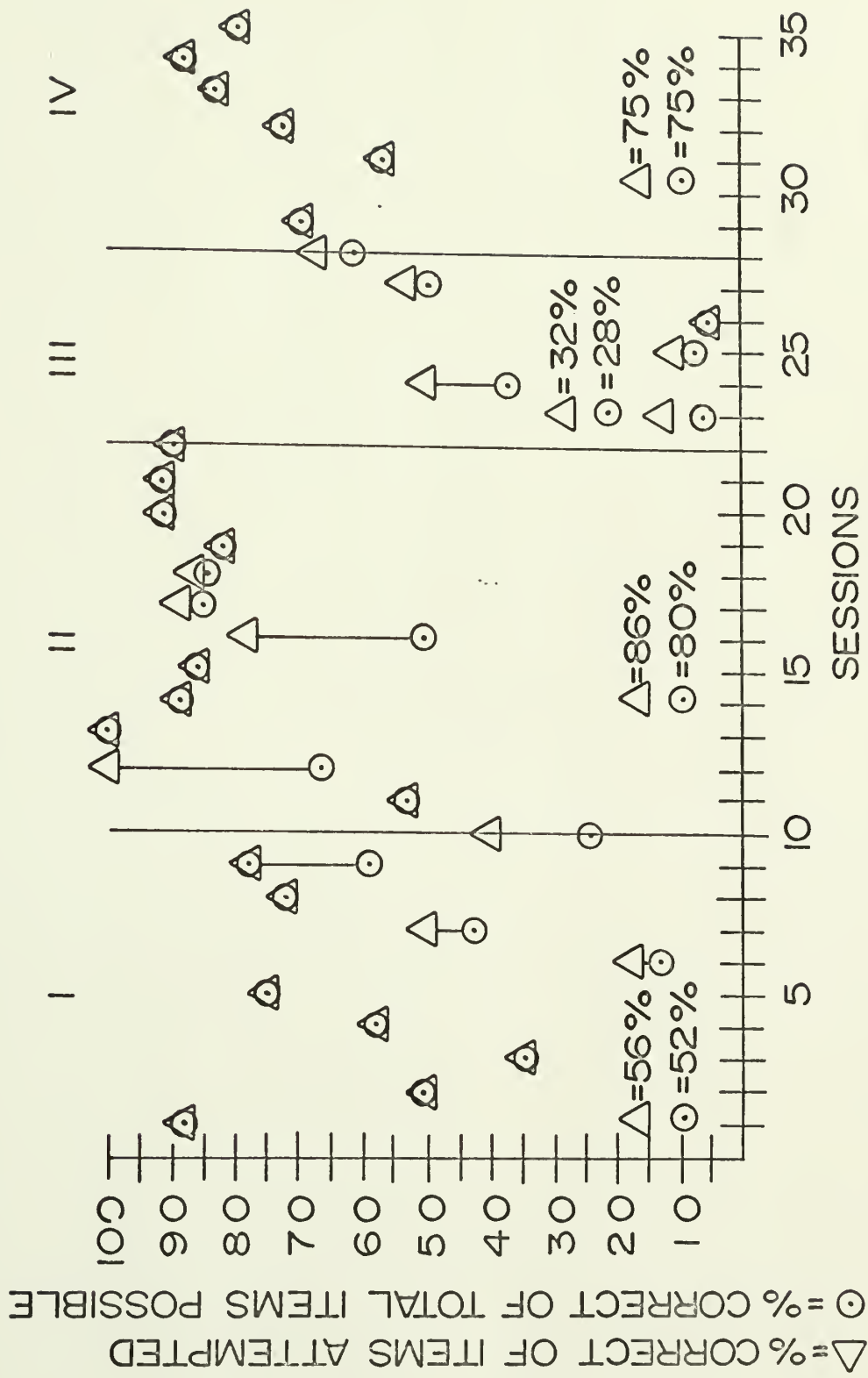


FIGURE 3. SUBJECT 1

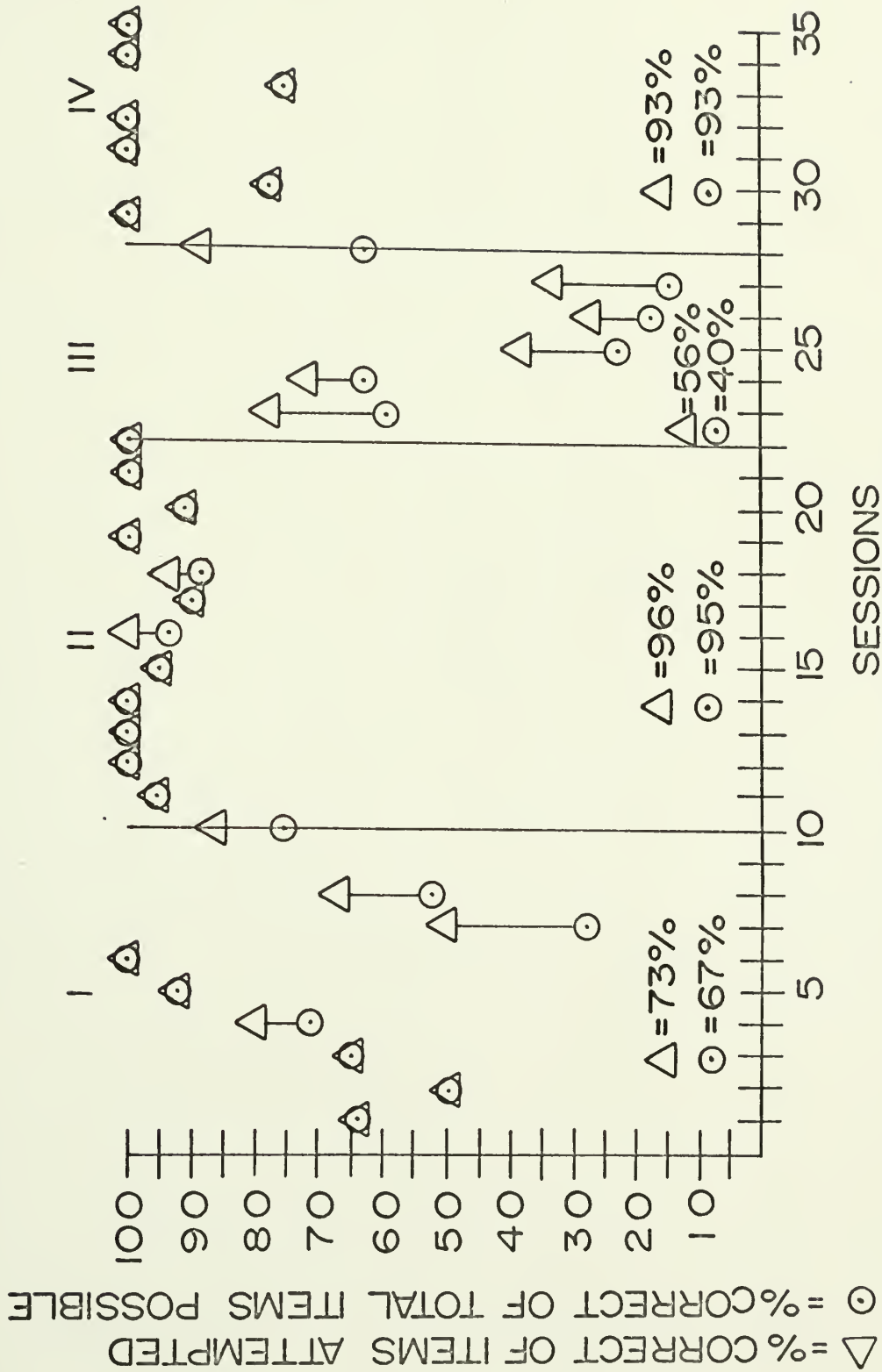


FIGURE 4. SUBJECT 2

formance during Baseline. During sessions 7 and 8 of Baseline and also during sessions 23, 25, 27 and 28 of Reversal, S_2 did not attempt many items but had a higher percentage correct on the items he did attempt. With a return of reinforcement, phase IV, the mean performance accuracy increased to 93%. Subject 2 was absent the days before sessions 30 and 33. S_2 was given an A for phases II and IV.

Subject 3 (S_3) was absent sessions 3 and 4. The mean percent correct of total items possible was 51% for phase I, 82% for phase II, 29% for phase III and 75% for phase IV (Fig. 5). The mean percent correct of total items attempted was 56% for phase I, 90% for phase II, 30% for phase III and 76% for phase IV. Subject 3 had an unstable Baseline ranging from 13 to 88% and attained a mean of 51%. With phase II (Instatement of Reinforcement Contingency) S_3 had an unstable set of performances for the sessions with a range from 59 to 100%. The extent of the range of performances decreased from 75% with phase I to 41% during phase II. During sessions 13 and 21 of phase II subject 3 did not attempt all items but was correct for each of the items he attempted. During session 20, S_3 made several arithmetic errors which employed most of his time and he did not have enough time to complete other items.

Termination of phase II and reversing to Baseline conditions resulted in a drop in mean accuracy to 29%. This value was 22% below Baseline. Performance during Reversal varied extensively ranging from 0 to 62%. This range was 13% less

than Baseline. Beginning with session 29 of phase IV (Reinstatement of Reinforcement Contingency) a rising pattern of improving performance was observed. Subject 3 attained a mean of 75% for phase IV. S_3 was given a B for phases II and IV.

Subject 4 was present for all experimental sessions. The mean percent correct of total items possible was 57% for phase I, 94% for phase II, 41% for phase III and 99% for phase IV (Fig. 6). The mean percent correct of items attempted was 62% for phase I, 97% for phase II, 45% for phase III and 99% for phase IV. Phase I (Baseline) was unstable with performance ranging from 25 to 100%. S_4 attempted fewer items during session 4 but attained a higher percentage correct for the items he attempted. Two days before session 6 the investigator observed that S_4 had turned in a laboratory report with the exact calculations of S_8 . The investigator did not approach nor question S_4 on the report but simply made a copy of the report and handed it back to him without comment. The following day session 6 was scheduled and S_4 achieved all the items presented to him while S_8 had an accuracy of 64% for the session. Following session 6, a drop in performance for S_4 was observed and performance fluctuated for the remaining sessions of Baseline. Instatement of Reinforcement Contingency of phase II resulted in an immediate high rate of response accuracy which continued throughout the phase. During session 18 the subject did not attempt all items that were

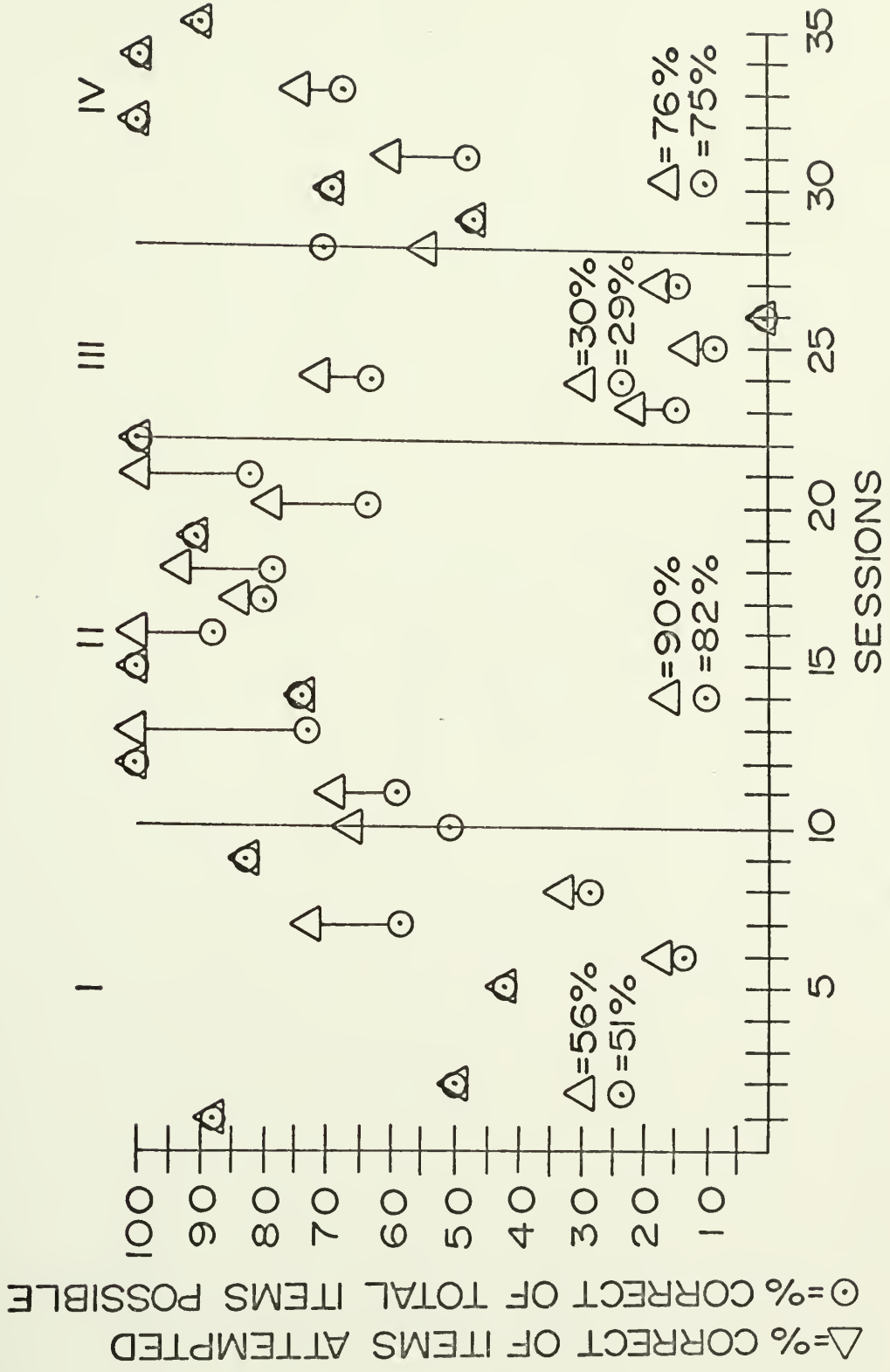


FIGURE 5. SUBJECT 3

presented to him but did achieve all of the items that he attempted. S_4 attained 94% of total items possible in phase II.

During the first session of Reversal, session 23, S_4 refused to attempt any items and sat at his place in front of the class with eyes transfixed. The investigator asked him after the session was completed why he did not attempt any items and the subject shrugged his shoulders and left. The mean percent correct for phase III was 41%. The figure is 16% lower than in Baseline. Performances during Reversal were unstable and ranged from 0 to 68%. The extent of the range of performances in phase I was 75% and was 68% in phase III. Reinstatement of reinforcement during phase IV resulted in an immediate high degree of accuracy with a mean of 99% for the phase. Subject 4 was given an A for phases II and IV.

Subject 5 was absent sessions 3 and 4. The mean percent correct of total items possible was 59% for phase I, 90% for phase II, 35% for phase II and 93% for phase IV (Fig. 7). The mean percent correct of total items attempted was 70% for phase I, 93% for phase II, 46% for phase III and 93% for phase IV. Subject 5 had an unstable Baseline ranging from 23 to 92%. During session 6, S_5 attempted only a small number of items and achieved most of the items he attempted. With instatement of reinforcement in phase II subject 5 showed a rapid improvement in accuracy and attained a mean of 90% for

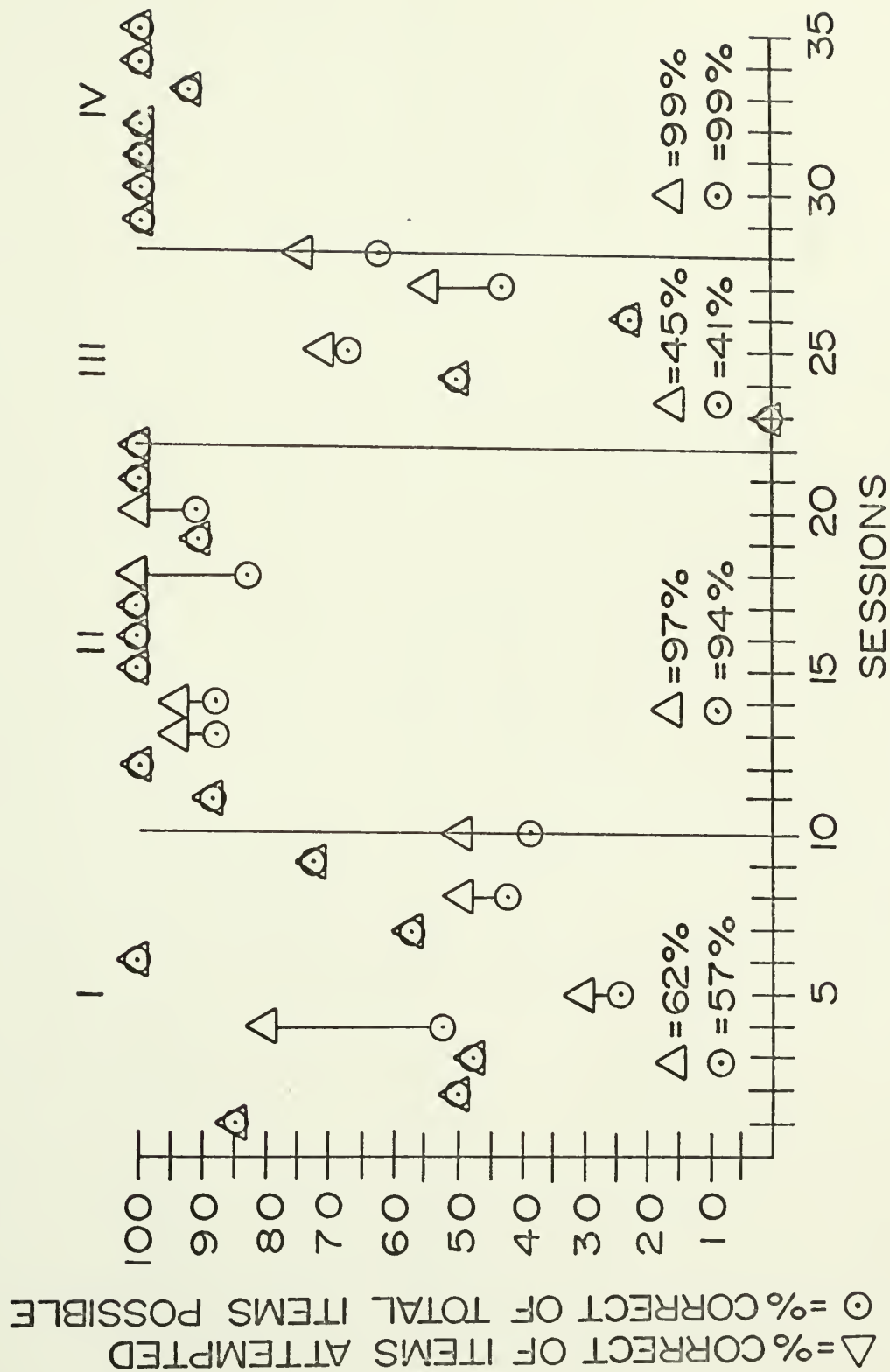


FIGURE 6. SUBJECT 4

the phase. At the announcement of termination of consequence S_5 became visibly upset and murmured several inaudible comments. S_5 approached the experimenter on two separate occasions and asked that point application not be discontinued. A mean of 90% for the total items possible was attained during phase II.

During phase III (Reversal) the mean accuracy on total items possible decreased to 35%. This represents a difference of 24% below phase I. Performance fluctuated from 14 to 62% during Reversal. During session 28, S_5 had a higher percent correct of items attempted compared with other sessions in the phase. Reinstatement of reinforcement during phase IV resulted in an improvement in accuracy with a mean of 93% for the phase. Subject 5 was given an A for phases II and IV.

Subject 6 was absent sessions 5 and 25. The mean percent correct of total items possible was 65% in phase I, 86% in phase II, 40% in phase III and 94% in phase IV (Fig. 8). The mean percent correct of items attempted was 71% for phase I, 93% for phase II, 54% for phase II and 97% for phase IV. The performance of S_6 varied extensively during phase I ranging from 22 to 100%. During sessions 7, 9 and 10 of phase I subject 6 did not attempt all possible items but attained a high percent correct on the items attempted. S_6 was 9% above the criterion level specified for terminating Baseline and instating phase II.

With the onset of consequence in phase II an increase

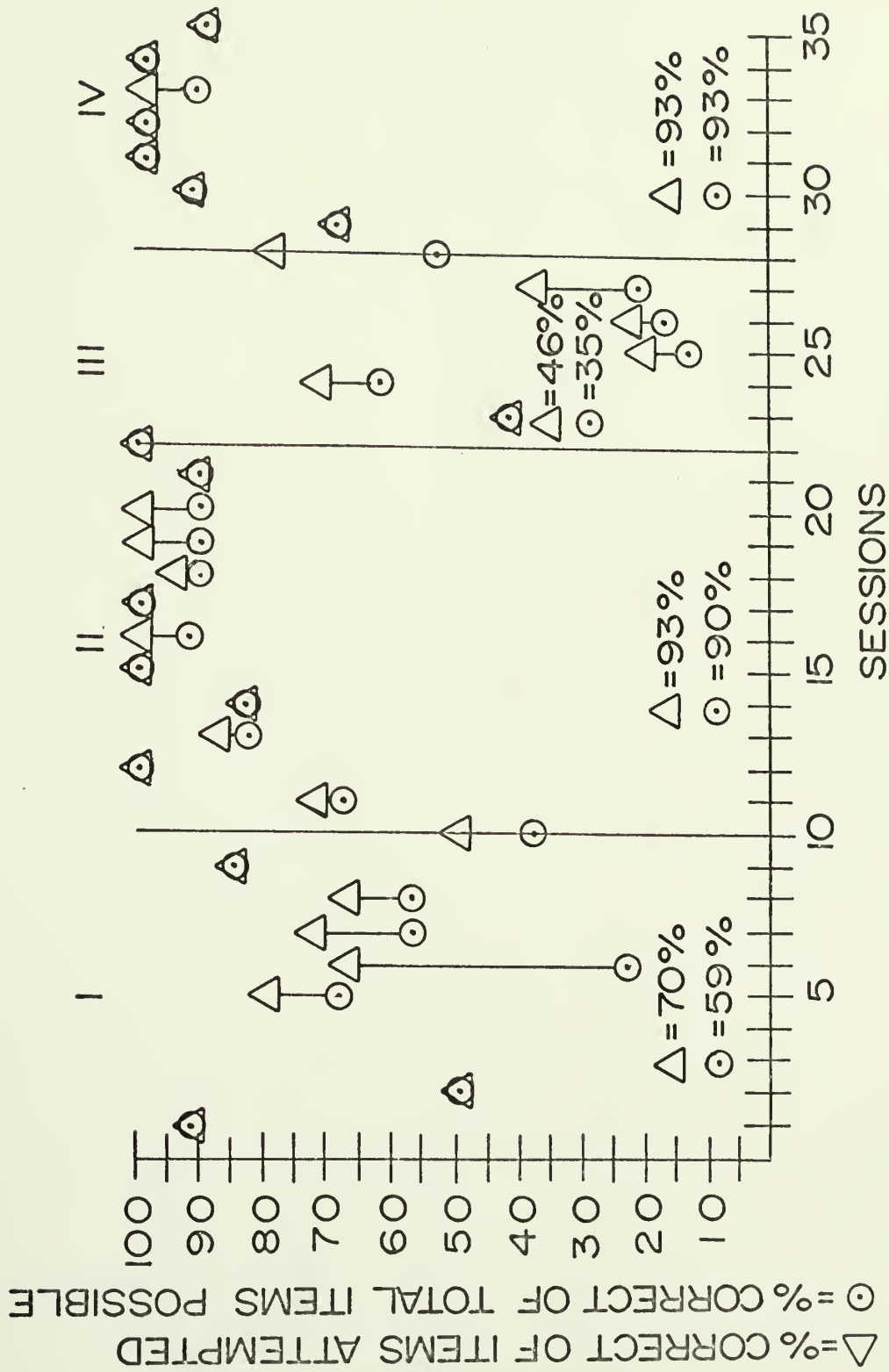


FIGURE 7. SUBJECT 5

in the percent correct of total items possible 65 to 86%. A rapid improvement in accuracy occurred in sessions 11, 12 and 13 followed by a consistent pattern of performance. During sessions 11 and 12, S₆ did not attempt all items but improved on the percent correct of items attempted. Reversal resulted in a rapid decrease in performance. Performance ranged from 8 to 76% for the phase. The mean percent correct of total items possible was 40% for phase III. This value is 25% below Baseline level. Reinstating the reinforcement contingency resulted in an increase to 93% correct of total items possible. Subject 6 was given an A for phases II and IV.

Subject 7 was absent sessions 4 and 27. The mean percent correct of total items possible was 56% for phase I, 86% for phase II, 39% for phase III and 94% for phase IV (Fig. 9). The mean percent correct of items attempted was 60% for phase I, 93% for phase II, 46% for phase III and 94% for phase IV. During Baseline his performance was unstable and ranged from 34 to 84%. Subject 7 attempted fewer items in sessions 5 and 10 but attained a higher percent correct of items attempted. The onset of phase II generated a pattern of general improvement from session 11 to session 22. During session 11, 13 and 14 S₇ did not complete all items possible but had a high percent correct on the items he attempted. The announcement of Reversal resulted in outward expression of unhappiness with an attempt to organize others in the class to

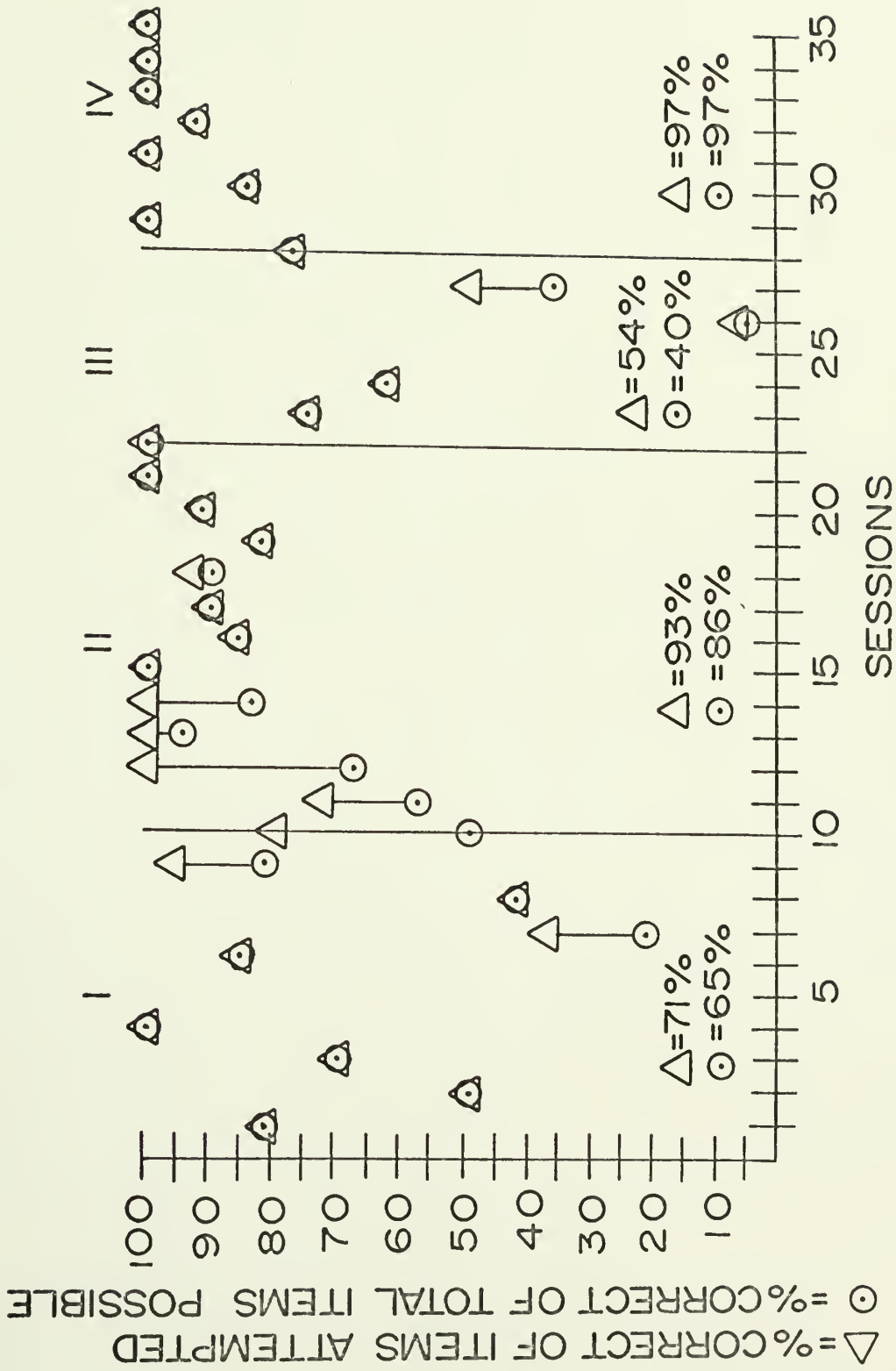


FIGURE 8. SUBJECT 6

support reconsideration of the withdrawal of points. Performance dropped rapidly from session 23 to session 26 with a mean of 39% correct of total items possible for the phase. The mean value of 39% was 17% lower than in Baseline. During session 28, S₇ did not attempt all items but had a high percent correct on the items attempted. Reinstatement of consequence during phase IV resulted in a mean performance of 94% for the phase. A small reversal was observed with sessions 31 and 32 followed by a pattern of improvement up to session 35. Subject 7 received an A for sessions II and IV.

Subject 8 was absent session 27 and 28. The mean percent correct of total items possible was 63% for phase I, 82% for phase II, 30% for phase III and 90% for phase IV (Fig. 10). The mean percent correct for items attempted was 66% for phase I, 91% for phase II, 33% for phase III and 90% for phase IV. With the exception of sessions 1 and 6 subject 8 had a slightly increasing but stable Baseline. During sessions 5 and 6 the subject did not attempt all items that were possible but attained a higher percent correct on the items attempted in those sessions. The beginning of phase II, (Reinstatement of Reinforcement Contingency) resulted with an increase in accuracy and a general pattern of improvement up to session 22. Sessions 12, 18 and 20 are noted for a high percent correct on items attempted. Reversal resulted in a decrease in performance to a mean of 30%. This value is 33%

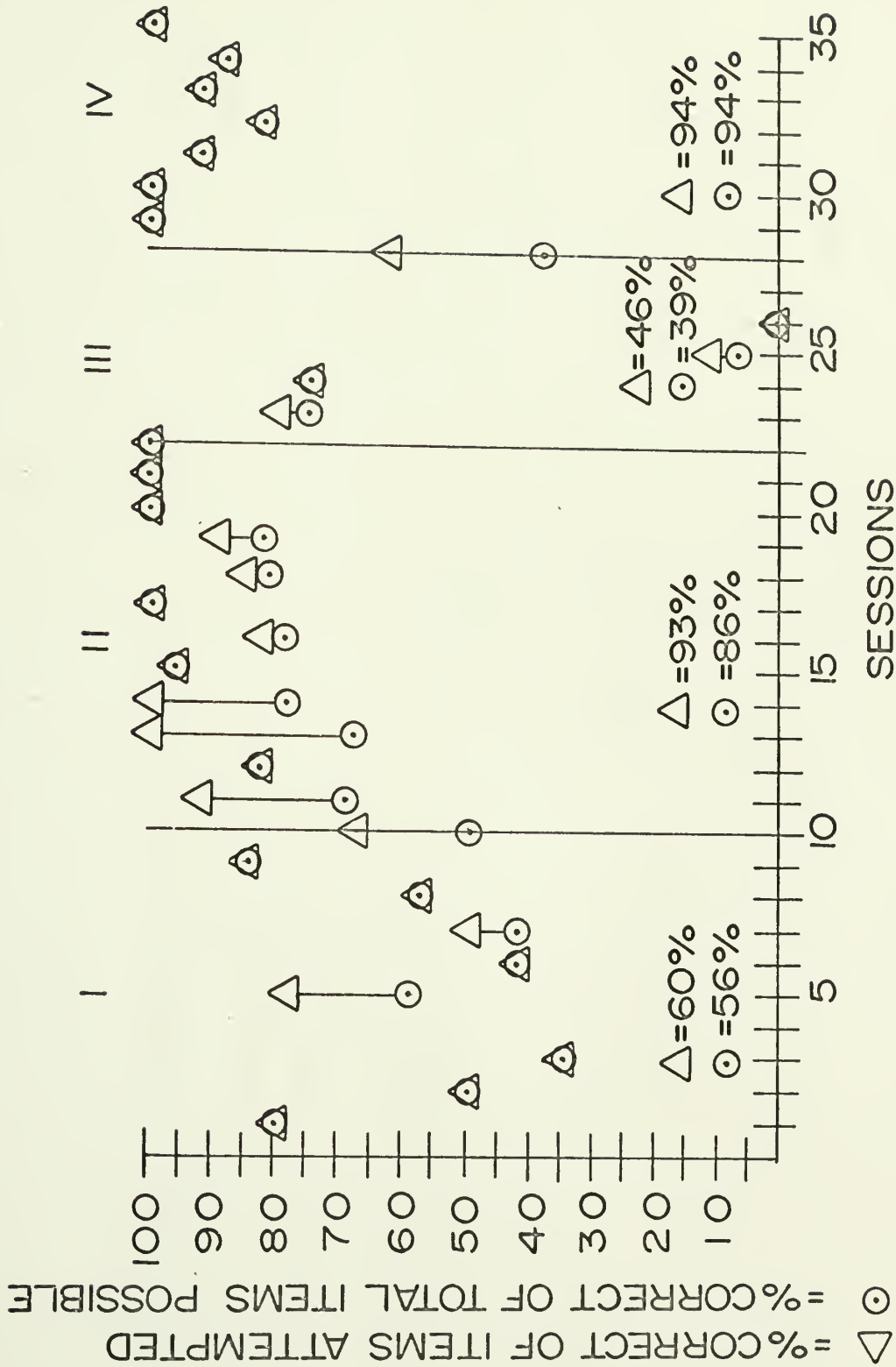


FIGURE 9. SUBJECT 7

lower than in Baseline phase I. Reinstatement of reinforcement resulted in an increase in the percent correct of total items possible for the session to 90%. A decrease in performance was observed for session 35. S₈ was given an A for phases II and IV.

Subject 9 (S₉) was absent sessions 16 and 31. The mean percent correct of total items possible was 55% for phase I, 78% for phase II, 30% for phase III and 65% for phase IV (Fig. 11). The mean percent correct of items attempted was 66% for phase I, 91% for phase II, 36% for phase III and 71% for phase IV. Baseline performance was unstable and ranged from 33 to 94%. During sessions 4, 5 and 6, S₉ attempted fewer items but attained a higher percent correct on the items attempted. This pattern of attempting only a limited number of items but attaining a higher percent correct on the items was also observed with sessions 11 - 14, 24, 27 - 29, and 33.

During phase II subject 9 showed a general improvement in performance up to session 14. Following session 14, performance varied from 81 to 100% with a high percent correct of items possible. Reversal resulted in performances which varied from 0 to 50%. The mean for the percent correct of items possible was 30% for Reversal and this reflects a decrease of 25% compared with Baseline. Reinstatement of reinforcement with phase III resulted in performance varying from 36 to 100% and a very unstable pattern. S₉ was absent on a

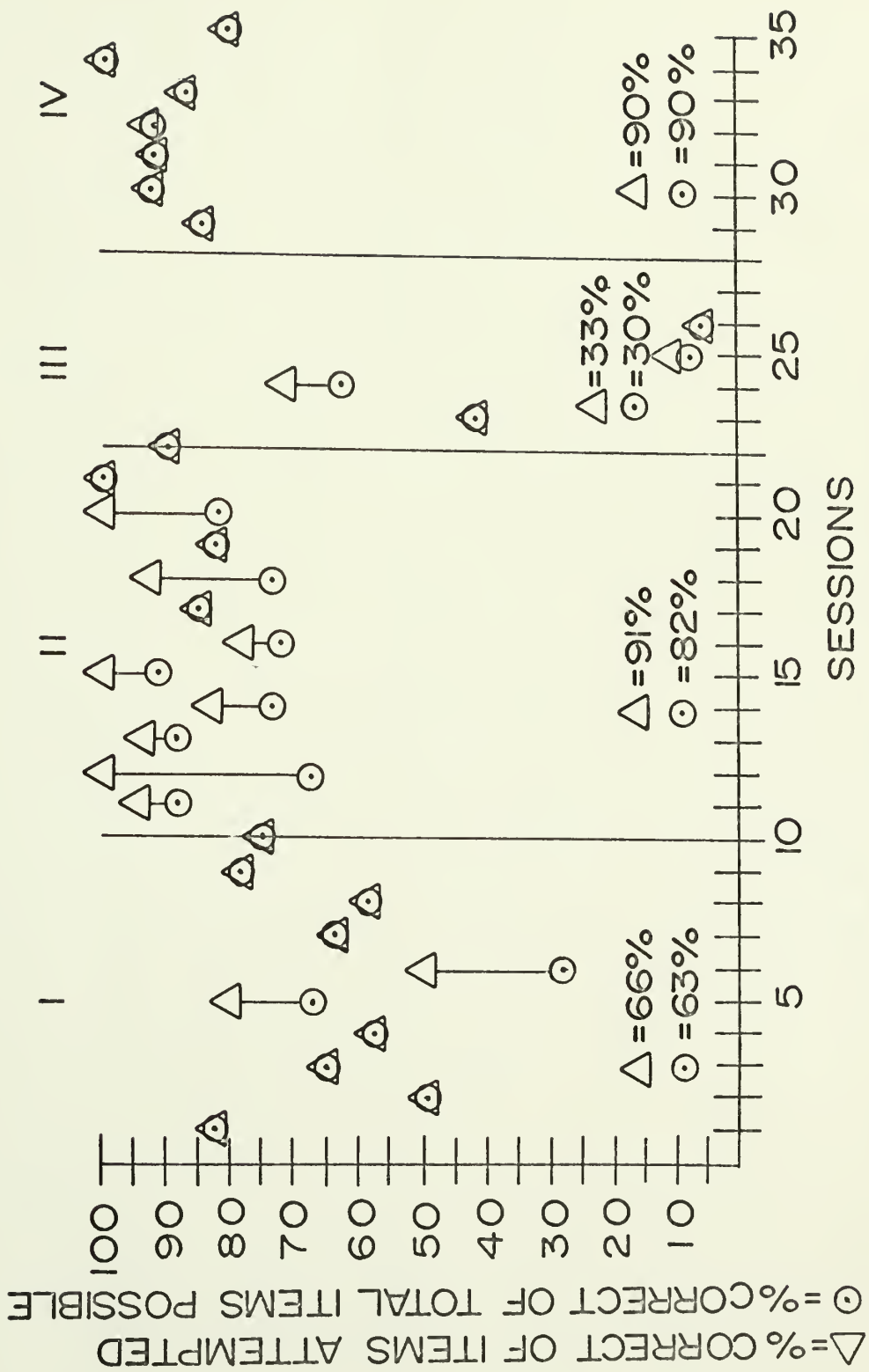


FIGURE 10. SUBJECT 8

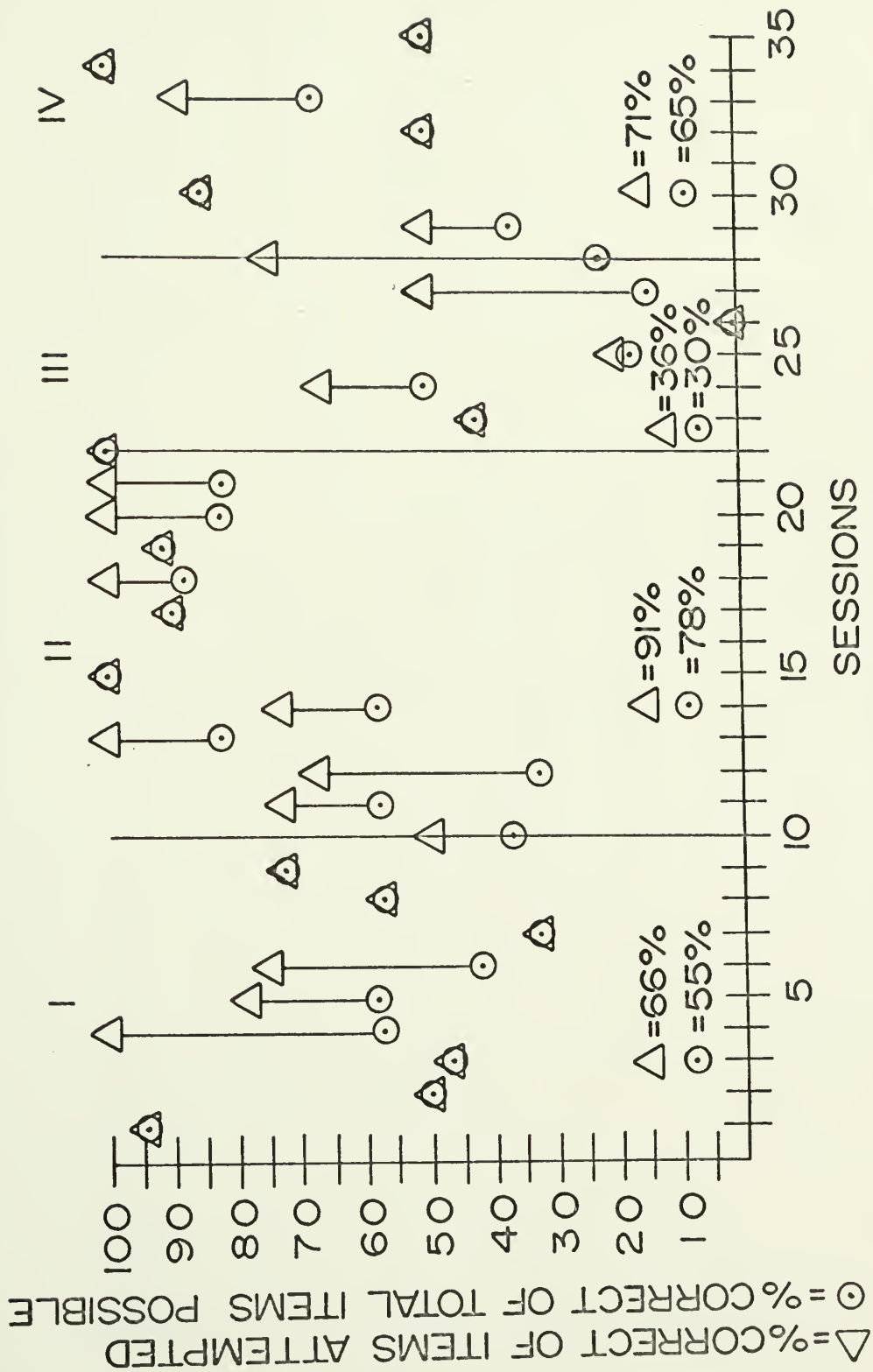


FIGURE II. SUBJECT 9

large number of occasions during phase IV and hospitalized twice. The mean performance for S₉ during phase IV was 65% and this was a decrease from phase II level of 78%. During sessions 25, 26, 27, and 28 of phase III and also session 29 of phase IV, subject 9 attempted only a few items and then put his head down and appeared to go to sleep while others around him continued on. Subject 9 was given a B for phase II and a C for phase IV.

Subject 10 was absent for sessions 5 and 33. The mean percent correct of total items possible was 52% for phase I, 83% for phase II, 33% for phase III and 92% for phase IV (Fig. 12). The mean percent correct of items attempted was 66% for phase I, 94% for phase II, 42% for phase III and 92% for phase IV. Performance during Baseline phase I ranged from 22 to 80%. During sessions 6 and 10 subject 10 did not attempt as many items as was possible but attained a high percent correct of items attempted. This characteristic was observed also for sessions 13 and 18 of phase II and also session 25 of phase III. With the onset of phase II the accuracy of performance among the sessions generally improved with reversals in sessions 13 and 18 as noted. During phase III, Reversal, the mean percent correct of total items possible decreased to 33%. This value was 19% below Baseline phase I level. Performance during Reversal also varied and ranged from 8 to 64%. The extent of the range of variation was 58% for phase I and 56% for phase III. The return of reinforcement during

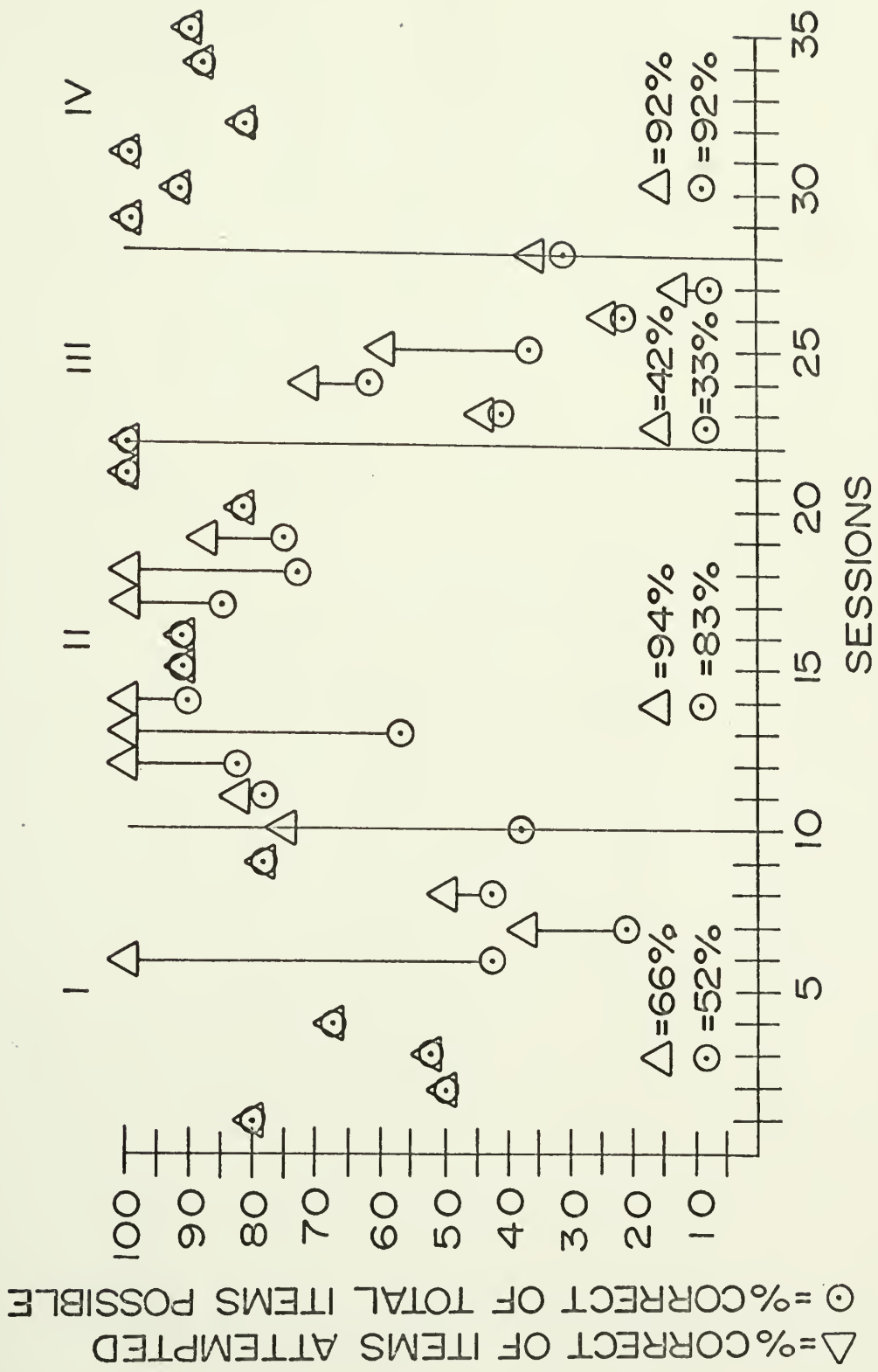


FIGURE 12. SUBJECT 10

phase IV resulted in an increased percentage correct of total items possible to 92%. A reversal occurred with session 32 followed by an increase in performance. S₁₀ received an A for phase II and IV.

Subject 11 was absent sessions 5, 26, 28 and 30. The mean percent correct of total items possible was 71% for phase I, 79% for phase II, 34% for phase III and 94% for phase IV (Fig. 13). The mean percent correct of total items attempted was 77% for phase I, 94% for phase II, 42% for phase III and 94% for phase IV. Performance during Baseline varied from 27 to 100% on the total items possible. Beginning with session 10 and continuing through most of the sessions in phase II and including session 23 of phase III subject 10 attempted fewer items but attained a high percentage accuracy on the items attempted. This phenomenon seemed to occur mostly in phase II. Examination of percent correct of total items possible during phase II showed a general pattern of improvement with a mean of 79 percent correct for total items possible. The difference between the percent correct of total items possible and the percent correct of total items attempted during phase II was 16% indicating a higher percentage correct on items attempted.

During phase III (Reversal), the performance decreased to 34%. This decrease was 37% below the performance level of phase I. Performances also varied during phase III and ranged from 0 to 64%. The extent of the range of variation

for phase I was 73% and was 64% for phase III. The reinstatement of reinforcement during phase IV resulted in an increase in performance to 94%. Performance stabilized at a high rate and did not show the same pattern as in phase II but both phases II and phase IV had a mean of 94% correct on items attempted. S₁₁ received a B for phase II and an A for phase IV.

Subject 12 was absent sessions 3, 4, 13 and 14. The mean percent correct of total items possible was 57% for phase I, 83% for phase II, 37% for phase III and 90% for phase IV (Fig. 14). The mean percent correct of items attempted was 63% for phase I, 88% for phase II, 41% for phase III and 90% for phase IV. Accuracy during Baseline ranged from 12 to 82%. S₁₂ had a higher percent correct on the items he attempted during session 7. In session 10 subject 12 had a low performance of 12%. The onset of reinforcement, phase II, resulted in a general pattern of increased performance. In session 16 a reversal of performance occurred but the percent correct of items attempted was high. S₁₂ was absent from class the day before session 16. The mean accuracy on the percent of items possible during phase II was 83%. Reversal, phase III, resulted in a decrease in performance to a mean of 37%. This value represents a decrease of 20% compared to the mean obtained in Baseline phase I. During phase III performance variation ranged from 7 to 62%. The extent of the range of performance for phase I was 70% and

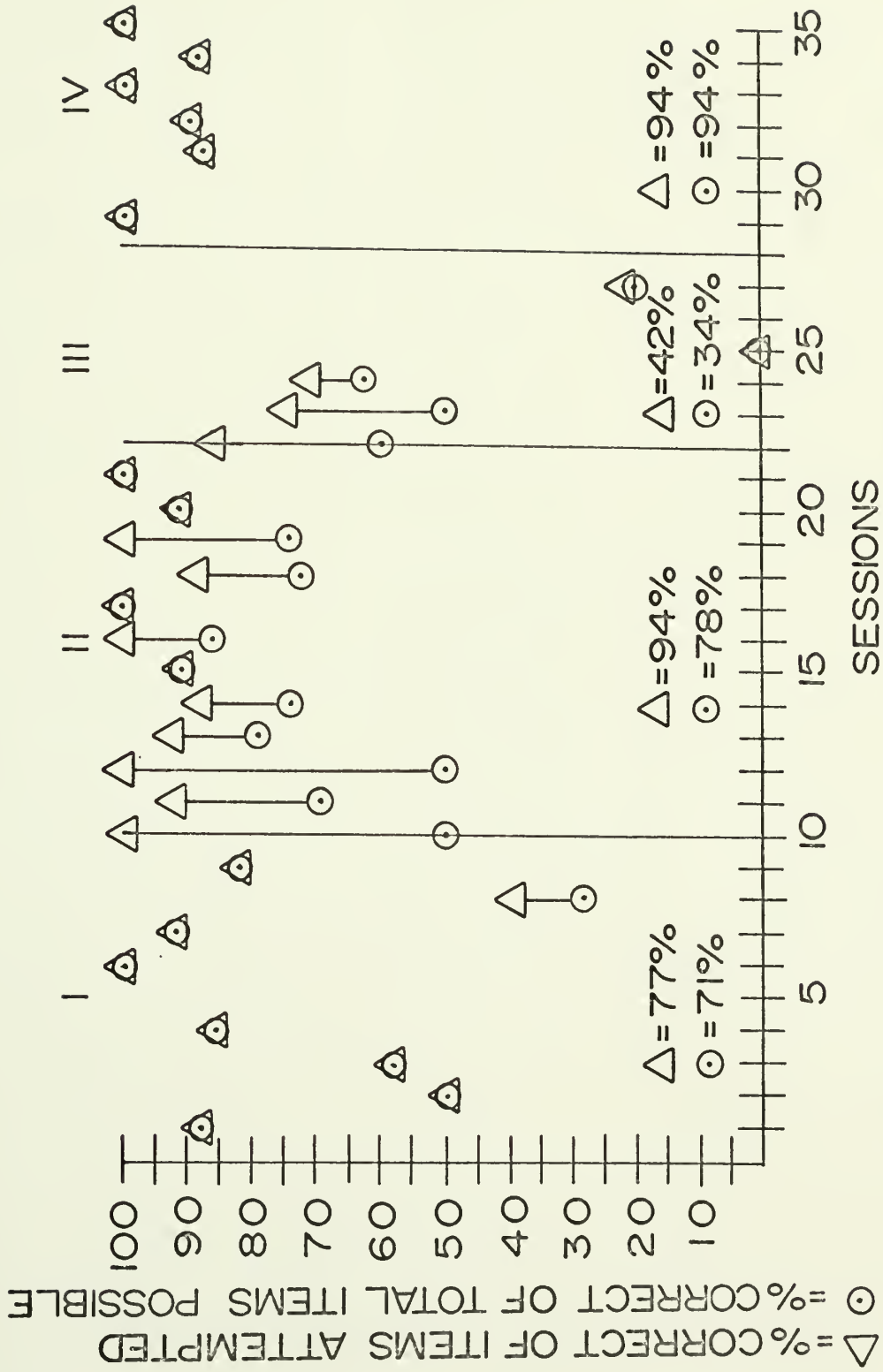


FIGURE 13. SUBJECT II

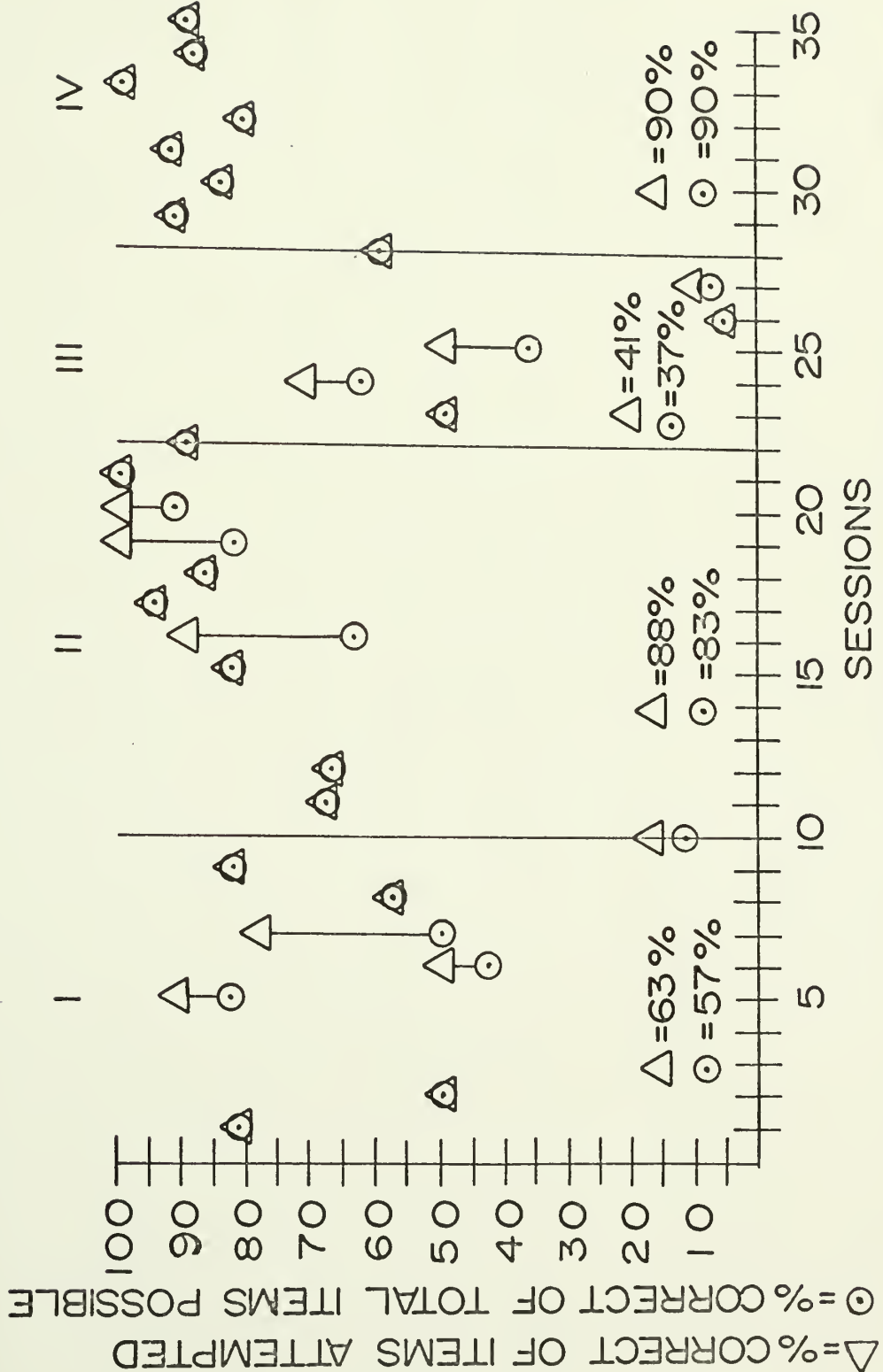


FIGURE 14. SUBJECT 12

was 55% for phase III. With the announcement that points would not be given at the end of phase II, subject 12 became very upset and emitted the comment that he was "just starting to do good in the course" and did not think it was "fair". With the reinstatement of Reinforcement Contingency, in phase IV, the accuracy in performance increased to 90%. S₁₂ received an A for phases II and IV.

Subject 13 (S₁₃) was absent session 6. The mean percent correct for total items possible was 68% for phase I, 92% for phase II, 53% for phase III and 96% for phase IV (Fig. 15). The mean percent correct of total items attempted was 72% for phase I, 96% for phase II, 58% for phase III and 96% for phase IV. During Baseline phase I, performance varied from 22 to 100%. For session 7, S₁₃ did not attempt as many items but attained a higher percent correct on the items he attempted. Subject 13 was 8% above the criterion level set for terminating Baseline and was one of the subjects who did not meet the instatement criterion. With the onset of reinforcement during phase II a high performance level was observed for all sessions except session 13. With session 13 a reversal occurred and S₁₃ did not attempt all items possible but attained a high percent accuracy on the items he attempted. S₁₃ became angered at the termination of consequence. Performance during phase III, Reversal, had a mean of 53%. This value reflects a decrease of 15% compared with phase I. Variation during phase III ranged from 7 to 87%. The extent of

the range for phase III was 80% and was 78% for phase I. Reinstatement of Reinforcement Contingency during phase IV resulted in a high level of stable performance with a mean of 96%. Subject 13 received an A for phases II and IV.

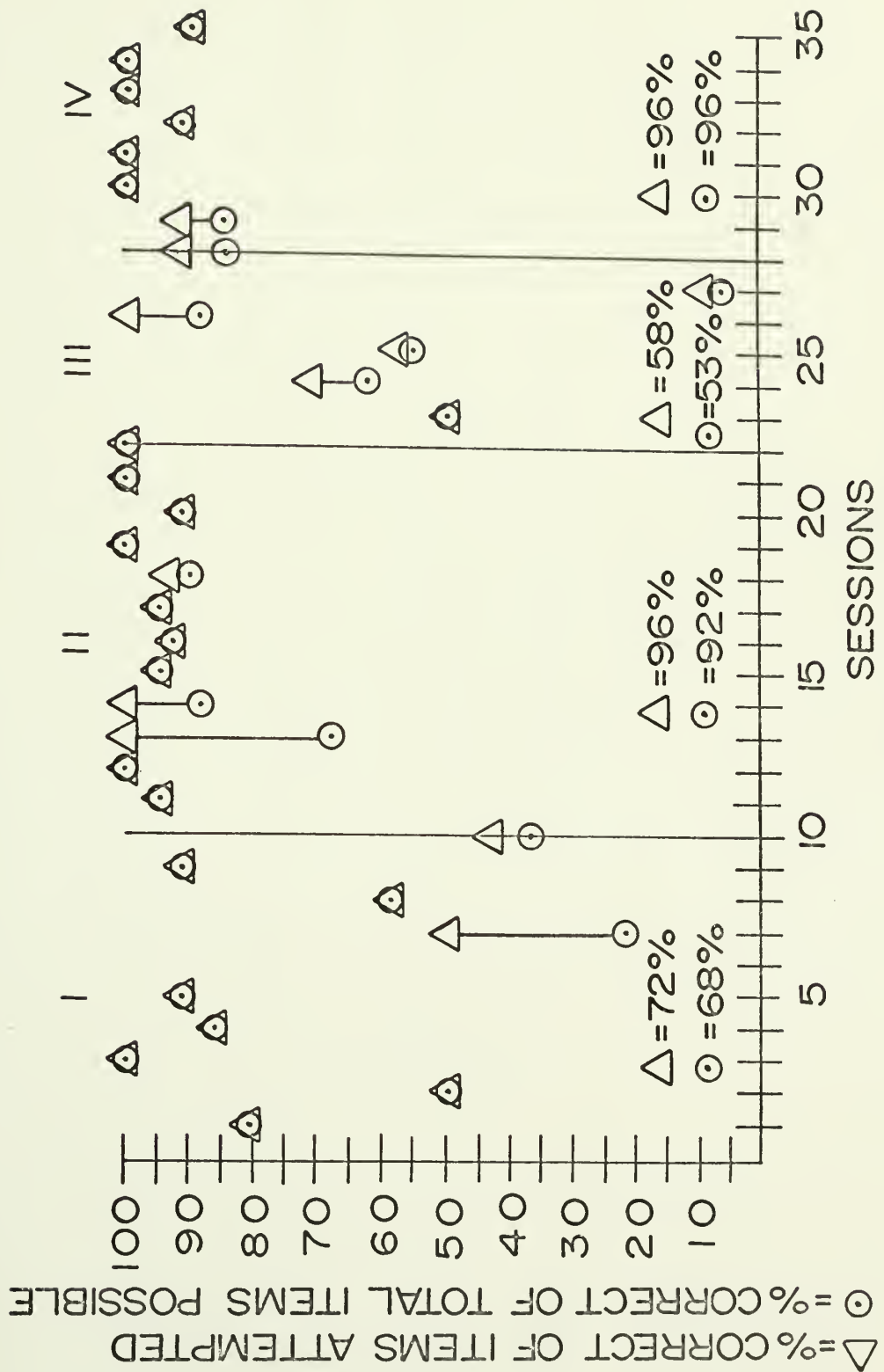


FIGURE 15. SUBJECT 13

C H A P T E R IV

DISCUSSION

Contingency management. The technology of teaching assessed in this investigation required the interaction of students within an educational setting (learning environment) that could be managed. The principles of operant psychology upon which the technology was based clearly suggested what environmental conditions would be required and what specific events within the environment should be managed. The environment that was managed consisted of both physical and human components. The teacher was considered part of the learning environment and his actions were contingent upon the emitted responses of students. It was therefore imperative for him to be able to make visual observations of specific events that were occurring within the environment. Analysis of the experimental data collected strongly support the expectations that were suggested by the principles of operant psychology.

Lists of performance objectives specified the complex behaviors in chemistry which were desired by the teacher. The MIVR system made possible the application of operant principles since the investigator was able to observe how each student performed during each of the four experimental phases. During the first and the third phases, the investi-

gator managed the environment in such a way that whenever a student emitted responses to items, the investigator made no attempt to consequence the composed responses. There was no change in the behavior of the contingency manager during these two phases.

During phases II and IV, the investigator again managed the environment but in such a way that whenever a student emitted a response and signalled for consequence, the investigator applied the explicit contingency of reinforcement to responses that were judged accurate. Examination of experimental data suggests that very positive results can be attained from the management of the learning environment. Students as a group showed an increase of 25% in the percentage correct of total items possible over Baseline resulting in a mean of 85% for phase II. Examination of the data for the group of students also showed a systematic positive increase in the percentage correct of items that were possible. During the last six sessions the mean percent correct of total items possible was 89% and this was also the same level as during phase IV when reinforcement was reinstated. Each of the thirteen students showed an increase in the percentage correct of total items possible during the phases when the reinforcement contingency was in effect.

In phases II and IV, the direct consequence of individually emitted responses to items that were judged to be

accurate served as positive reinforcing stimuli. Although the application of an explicit reinforcer, backed up by grades, served as positive reinforcing stimuli, the possibility clearly exists that other reinforcers may have been operating during phases II and IV. A social reinforcer (which is believed to have had an effect) was associated with the posting of performance data of all students within one hour after the experimental session was completed. Posting of results was necessitated because the physical constraints of the experimental environment permitted only half of the students to receive the explicit contingency of reinforcement at one time. As a result of this constraint, there was a delayed knowledge of results by those students who were not seated at MIVR stations. Students who were not seated at MIVR stations, and also those students who were, came into the classroom to observe their posted data.

Smiles, gestures of satisfaction, expressions of friendly competition and other social operants were emitted and exchanged by students among each other as they clustered around the posted results. On the day an experimental session was conducted and performance results of all students were posted, most of the students came into the room to observe their results at least once and often more than once. In addition to observing their results the day the experimental sessions were conducted, students also clustered around the bulletin board on other days when normal instructional activities were conducted in the classroom. The investigator observed the

phenomonon developing and made every attempt not to be in the immediate vicinity of the bulletin board on those occasions when students could enter the room and observe their posted data. The experimenter also made every attempt not to pay direct attention to students as they engaged in the emission of spontaneous social behaviors on those occasions when they visited the bulletin board.

The termination of consequence at the end of phase II abruptly interrupted the application of the explicit reinforcement contingency. Performance for the group decreased sharply and the mean percent correct of total items possible fell 23% below Baseline level of 60%. Although Skinner (1969) clearly suggests that operants will become extinguished if the contingency of reinforcement is withdrawn, the operant levels during Reversals applied to infra-human organisms and the operant levels which have been examined with humans have not decreased below Baseline level when the reinforcement contingency was removed. The observation of performance below Baseline during the Reversal phase suggests the occurrence of other phenomena.

Examination of student data indicates that each member of the group was above average in ability. During phase II, examination of performance data for the group indicated a systematic improvement from the beginning to the end of the phase. During phase II each individual student showed either an immediate high level of performance within the first few sessions, or showed a fairly systematic pattern of improvement

throughout the phase. It is quite possible that the student's performance came under the control not only of the explicit contingency of reinforcement that was administered by the investigator, but also the social reinforcers which were probably operating on those occasions when students observed their posted data. It would also seem that the behaviors of students that were related to the instructional activities that they were engaged in prior to consequence may have systematically come under the control of both the explicit and the social reinforcing stimuli that were in effect. Grades were positive reinforcers for these students and they were meeting with success during phase II. It is quite possible therefore that the possible removal of the explicit reinforcement contingency may have served as a pre-aversive stimulus whose properties became manifested at the termination of phase II. If indeed, the contingency of reinforcement did serve as a pre-aversive stimulus then it is possible that the many behaviors that students engaged in while conducting the instructional activities related to the performance objectives would also assume aversive properties. The development of aversiveness would possibly explain the performance during Reversal phase being lower than Baseline because at Baseline, the events occurring could be considered to be neutral in that students had not been exposed to any prior explicit contingency of reinforcement.

A decreasing number of students came in looking for

posted results during Reversal Phase III on the days when experimental sessions 23, 24 and 25 were completed. After session 26, the students no longer approached the bulletin board on other days when normal instructional activities were conducted. It seems clear that this class of operants was extinguished.

On the day students were told that they would again be receiving points leading to grades, there was a spontaneous outburst of happiness on the part of the students together with several questions about reposting results. During phase IV, Reinstatement of Reinforcement Contingency, the students again returned to a pattern of checking posted results as in phase II and also exchanging in social amenities as before.

Mediated Interaction. The inability to monitor specific performances of several students almost simultaneously and also to be able to immediately apply exact reinforcers contingent upon the emission of desired behaviors by those students has limited the application of operant technology in the classroom. Traditional classroom practices are inefficient in being able to monitor individual student performances and also in being able to schedule the application of appropriate reinforcers. Skinner (1968e), points to some of the questions which must be answered to improve teaching.

What behavior is to be set up? What reinforcers are at hand? ... How can reinforcements be most efficiently scheduled to maintain the behavior in strength?

In this investigation, efficiency in scheduling of reinforcers was made possible through the use of a Mediated Interaction Visual Response (MIVR) system designed by Wyman (1968b). Visual observation of constructed responses that were emitted by students was easily accomplished. The projected response images were clear and neither the students nor the investigator experienced any difficulty in operating the MIVR system. Mediated interaction through visual observation of constructed performances provided the capability of scheduling and applying explicit reinforcers. Students seated at MIVR stations could be consequenceed individually as they constructed items. The time required for different students to construct responses varied with each student and seldom did any two students complete an item at any one instant. After a student signalled to have his performance assessed, the investigator required only a few seconds to assess the response and apply the contingency. A unique feature of using the MIVR system was that several students could be attempting different items at the same time but the time required to assess the performances was very short, seldom exceeding five seconds. Queues of over ten seconds seldom occurred and as a result the students' time was most efficiently used.

Students participated actively in the process of constructing responses and seemed to enjoy working at the MIVR stations as evidenced by the verbal comments, smiles and

written statements (appendix 3). The technology of teaching that was conducted in this investigation would not have been possible without the use of Mediated Interaction Visual Response system. The data presented in Table III clearly indicate that immediate consequence of constructed responses which is possible when students use the MIVR system permits a degree of control over complex chemistry behaviors which is not possible through delayed presentations of consequences of even one hour.

High School Chemistry. Serious attempts are being made to develop programs to individualize instruction in chemistry. The most advanced program is one which has been evolving since 1968 under the direction of DeRose (1970c). A central feature of his program and to other programs to individualize instruction has been the development and use of performance (behavioral) objectives. Even with a program of individualized instruction students do not seem to take advantage of the opportunities for individual progress, DeRose (1970d).

The independent study program now specifies a basic set of objectives to be achieved, provides for individualization through optional objectives and permits each student to learn at a pace geared to his own particular talents. But the assumption that students will make the best use of their time and pace themselves in line with their potential

has not been supported in practice.

The problem of motivating students to learn lies in establishing and applying effective contingencies of reinforcement, Skinner (1968f) and Nesselroad (1970d). In order to do so the teacher must be able to monitor, assess and consequate the desired performances of students and he must be able to do so consistently in accordance with the contingencies of reinforcement available. Programs of individualized instruction, it would seem, should be assessed in accordance with various schedules of reinforcement contingencies which are available to students. It is possible that a program of individualized instruction which does not provide for alternative contingencies of reinforcement may in reality not be to the advantage of the students in the program. In this investigation, a specific contingency of reinforcement was available and seemed to work effectively for those students who were enrolled.

Grades. Grades are reinforcers. If grades are properly applied, they can serve as positive reinforcers and their contingent application can sustain a wide range of behaviors. If grades are not properly applied they can become negative reinforcers and their contingent application can sustain a wide range of undesirable behaviors.

Part of the technology in this investigation was the identification and application of positive reinforcers.

The technology developed also required the management of a system of positive reinforcers. School policy required that letter grades be issued on a quarterly basis to students. The research design required the manipulation of a contingency of reinforcement off and on. This manipulation resulted in periods of time when the reinforcement contingency was not in effect and consequently the letter grades would not have been given. To overcome this problem the investigator issued letter grades based upon tests and lab reports but did not manipulate these grades. When experimental phases two and four were in effect, seventy percent of each student's grade was then made contingent upon the results of his performance during experimental sessions.

The grading system employed was easy to administer since one point was given for each item the student was judged accurate on. The percentage correct of total items possible then became the criterion for determining the student's grade along with any systematic improvement or decrease in performance among the sessions of the experimental phases.

The application of grades and marks has been a problem with other programs to individualize instruction. DeRose (1970e) had to adjust his program of individualized chemistry to conform to the grading policy of the school. In order to

operate a program of individualized instruction, DeRose had to specify a basic set of objectives that each student was expected to attain each six weeks. At the end of a six week period of time each student was given a letter grade that was based upon the average of his "quantitative" and "qualitative" performance on the objectives he achieved. The quantitative performance was determined by the percent of objectives the student achieved out of the required number. The qualitative performance was based upon an arbitrarily established number of points for each objective. A student was expected to attain a minimum of seventy percent of the possible number of points for each objective and recycled until he met this criterion. After he met the minimum criterion of performance for an objective in which he had to recycle, the student was then given an average of his performance on all the assessment attempts that were required.

Grades can be a major category of reinforcers for many students if they are managed properly. Most schools employ a procedure of applying letter grades and it would seem that this category of reinforcers could effectively be applied if the nature of their relationship to the process of learning was more widely known. Whether schools employ letter grades or some form of pass-fail or pass-no-record is not important. What is important is that contingencies of reinforcement be

made available which can be backed up by letter grades or other contrived or natural reinforcers which are both salient and desirable to the student.

Summary. This investigation was centered upon an attempt to develop a program to teach high school chemistry more effectively. In order to do so, the investigator had to develop a technology of teaching. The technology of teaching was based upon the principles of operant psychology. The field of operant psychology is based upon extensive research with sub-human organisms and more recently with human behavior.

Several basic conditions were required in the technology that was developed. The first condition was to specify precisely what the student taking Chem Study chemistry was expected to do. This was accomplished by writing and using lists of performance objectives. The second condition was to consider how a traditional learning environment could be changed so that the principles of operant psychology could be employed as part of the technology. This second condition was achieved by the use of a new innovative performance monitoring system, the Mediated Interaction Visual Response (MIVR) system. The third condition was to identify a reinforcer that would be effective. Grades were the reinforcer used and a contingency was developed which associated the reinforcer with specific

performances of students.

The investigator was assigned to a class of chemistry students and had no control over the numbers of students that were assigned to the class or their background. No special considerations were extended by the administration in order to conduct the investigation except for their approval to conduct the study and for the installation of a MIVR system. Subsequent action by the administration after the investigation was completed resulted in an expenditure of moneys to install a MIVR system permanently and to consider other ways of using the system to individualize instruction.

The results of the investigation clearly demonstrate that when complex student behaviors in the content area of high school chemistry were reinforced, each individual student in the class attained a remarkably higher percentage correct of the total items possible was achieved. Accuracy increased from 60% during a Baseline period when students were not reinforced to 85% when an explicit reinforcer was introduced in phase II of the investigation. When reinforcement was withdrawn, the average student performance dropped to 37% of the total items possible. Finally, when the reinforcement of student performances was reinstated, the average performance of the group increased to a high of 89%.

The results of the investigation demonstrate the extensive power of being able to observe complex student performances and also be able to explicitly reinforce those performances which are desired. Performance monitoring was made available only through the use of a Mediated Interaction Visual response (MIVR) system.

Implications for Further Research. This investigation has demonstrated that operant principles can be successfully employed to aid students in the acquisition of performances related to high school chemistry. A technology of teaching was required and its development has generated a number of general and specific questions related to the technology and its components.

The technology employed in this investigation was developed and was focused upon the teaching of high school chemistry at the public secondary school level. Programs of research should be developed which would focus upon other science and non-science content areas at the elementary and the secondary levels. The research programs should focus upon exploiting the Mediated Interaction Visual Response (MIVR) system to the ultimate benefit of the student.

An important area to be explored is the long range effect on retention of performances which are emitted by students under a schedule of continuous reinforcement such as is found in this investigation. Another important area of research

would seem to be to determine the effects of varying schedules of reinforcement on student performance acquisition and performance retention.

If the effects of a technology of teaching are superior to other instructional methodologies, it would seem that these effects could be investigated and also demonstrated by control and experimental groups.

A systematic investigation should be initiated to identify, record, store and make available to other teachers optimum contingencies of reinforcement and strategies of instruction for students having a more divergent academic background than the members involved in this study.

An area of investigation arising from the technology developed would be to assess the differential effects of having explicit contingencies of reinforcement administered by students, or paraprofessionals. It would seem that if a technology was developed properly, some routine activities could be conducted by subprofessionals resulting in an economy of time for more professional activities.

The entire area of preparing students to embark on a career of teaching would seem to be related to a technology of teaching. Wyman (1969b) has suggested that part of a teacher's period of training should be directed at ascertaining how the teacher affects the learning of his students. It

would be most appropriate to investigate the effects of having practice teachers or interns become involved in "A Behavior Oriented Initial Teaching Experience."

Extensive research efforts have been conducted in the past decade on attempting to compare the effects of using films, television, slides and a number of other instructional software materials to help groups of students learn. The great majority of this research has given results which have been nonsignificant. The individual learner in many of these studies has been involved as a passive receiver of projected information or has been involved in selecting an appropriate response from a set of alternative responses after viewing materials. Carpenter (1970) comments on this problem and calls for active student responses of all types. He also suggests that instructional media systems should provide for events which are reinforcing to the students who actively are involved.

There has been neglect in media research of the requirements for active response to instructional materials. The misconception is that significant amounts and relevant kinds of learning can occur without personal involvement, active responses and repeated practices. These must all be included

for appropriate, reinforcing kinds of learner materials. Uses of instructional media without requiring response, practice, and participation have led to many programs being of low quality and lesser effectiveness for learning than was possible and desirable.

The Mediated Interaction Visual Response (MIVR) system appears ideally suited in being able to provide for active interaction with a wide range of instructional materials. The MIVR system overcomes many of the limitations of those systems which offer only multiple choice response activities. The MIVR system provides for instantaneous feedback of information of all types to the teacher and to other students and this information provides the opportunity for personal involvement by the teacher and other students. This information feedback is important for its reinforcing properties and also serves as the basis for diagnosing and remediating specific learning problems that students may emit. Further research should be conducted to examine how the MIVR system can be employed in an instructional systems approach to solving specific learning problems.

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APPENDIX I
DEFINITION OF TERMS

- BASELINE: The experimental phase prior to instatement of specific contingencies of reinforcement.
- CONSEQUATION: Reinforcement of desired emitted performances.
- CONTINGENCY: A predetermined strategy or activity dependent upon the emission of behavior.
- CONTINGENCY MANAGEMENT: The administration of contingencies according to some predetermined plan.
- CONTINGENCY OF REINFORCEMENT: The relationship which prevails between behavior on the one hand and the consequences of that behavior on the other.
- CONSTRUCTED RESPONSES: The emission of a performance by a student which normally excludes the selection of multiple choice type items.
- DEPENDENT VARIABLE: In this investigation, the percentages of accurately emitted performances out of the total number of stimuli items in an experimental session.
- EDUCATIONAL SETTING: The specific environment utilized for either the conduction of some instructional activity related to specified performance objectives or the environment required for contingency management.

- INDEPENDENT VARIABLE: The application of explicitly specified contingencies of reinforcement after baseline determination.
- INSTANTANEOUS STATEMENT: The initiation of contingencies after the baseline.
- ITEM: A specific stimulus which is related to some specified performance objective.
- LEARNING: The relatively permanent change in the behavioral tendency of a student as a result of reinforced practice.
- PACKAGE: A set of instructional materials which normally includes lists of performance objectives together with suggested procedures for performance acquisition.
- PERFORMANCE: A behavior emitted by a student normally under the control of voluntary muscles.
- PERFORMANCE ASSESSMENT: The procedures employed to determine the extent of a student's repertoire.
- PERFORMANCE OBJECTIVE: A statement of what a student should be able to do after completing some instructional activity.
- PERFORMANCE MONITORING: The methods employed by teachers and other individuals to observe student performances.
- REINFORCEMENT: The application of salient and desirable

consequences contingent upon the emission of desired performances.

REMEDICATION: A contingency available in which an inaccurate or undesirable performance is corrected usually at the time of occurrence.

REPETOIRE: The supply or set of behaviors or performances available to a student and capable of being emitted with appropriate stimuli.

CONTINGENCY MANAGER: The teacher or individual responsible for the arrangement of materials and the management of contingencies.

TRADITIONAL: In this study, the chemistry practices and curricula employed prior to the NSF improvement programs. (In no way does the use of the term by the author, suggest or imply any negative practices.)

APPENDIX II
CONTENT COVERED DURING
EXPERIMENTAL SESSIONS

Session 1.

Given a set of fifty three statements about a burning candle, be able to identify those which are observations versus those which are interpretations.

Given a set of eleven statements about a burning candle be able to identify those which are quantitative and those which are qualitative.

Session 2.

Given experimental observations on the melting order of various substances and also the melting temperatures of the substances, be able to identify at least four regularities which exist among the substances and their temperatures.

Session 3.

Given experimental data on the melting and heating of a pure substance, be able to construct a properly labeled cooling and heating curve from the experimental data.

Using the plotted experimental data, be able to identify the processes that are occurring at various positions on the heating or cooling curve.

Given the experimentally plotted data on the fusion

or melting of a pure substance, be able to determine the melting or fusion temperature from the plotted information.

Given the experimentally plotted data on the fusion or melting of a pure substance, be able to write a short statement on the effect that a change in mass of the pure substance would have on the shape of the curve.

Session 4.

Given experimentally observed data on the burning of a candle in a closed container, be able to state the names of three substances produced in the burning process.

Given experimentally observed data on the substances produced when a candle burns in a closed container, be able to state supporting evidence on nature of the substances produced.

Be able to identify the source(s) of the products obtained in the combustion of a burning candle.

Session 5.

Given experimentally observed data on the heat liberated by a burning candle, be able to derive the mass of substance burned and the uncertainty in this value.

Given experimentally observed data on the mass of water heated by a given mass of burned candle, be able to derive the uncertainty in the mass heated and the uncertainty in the temperature of the water heated.

Given experimentally observed data on the heat liberated by a burning candle, be able to compute the quantity of heat energy needed to warm a mass of water.

Given experimentally observed data and the derived values for temperature and mass from the data on a burning candle, be able to calculate the heat of combustion per one gram of substance burned.

Using the experimentally observed data, from the heat liberated from the solidification of a given mass of wax, be able to calculate the heat of fusion per gram of wax involved, and calculate the uncertainty associated with this value.

Be able to write a short statement explaining why the heats of fusion or combustion as calculated from experimental observation would be higher or lower than expected.

Session 6.

Given experimentally observed data on the volume of gas collected, be able to derive the apparent mass of the gas and calculate the uncertainty in the derived value.

Given experimentally observed data on the volume of gas collected and assuming equal displacement of air to attain this volume, be able to compute the mass of air displaced by this volume of gas under the experimental conditions.

Be able to calculate the uncertainty in the mass of air displaced by the observed experimental volume of gas collected.

Given the masses of oxygen and that of an unknown gas, be able to calculate the ratio of the masses for the gases when their volumes, temperatures and pressures are equal.

Session 7.

Given a volume X of a container and a known gas Y, be able to calculate the mass of gas Y needed to fill volume X under the given conditions.

Given a set of three gases at normal temperature and pressure conditions, and some common observations of these gases, be able to identify and state the differences among the given gases that would account for some additional observed properties of the gases.

Given four sets of property differences between two gases, be able to identify which set of differences accounts for some added observations of one of the gases.

Session 8.

Given the combining volumes of gases, be able to apply Avagadro's hypothesis to predict the combining volumes.

Be able to determine the number of molecules of a gas that would be produced in a given gas reaction.

Given the masses for two different gases that were

observed under similar conditions of volume, temperature and pressure, be able to compute the ratio of the weight of one molecule of gas to another molecule and state any guiding principles needed in answering this question.

Given the names and the combining volumes of two reactant gases and the name and combining volume of the product gas produced in a reaction, be able to use this information together with the number of molecules of each reactant gas to predict the number of molecules of product gas that would be required.

Given numerical values for the combining volumes of two reactant gases to produce a third volume of product gas, be able to predict the volumes of product gases when given different initial values of the same reactant gas volumes.

Given numerical combining volume gas data, be able to prove that if either an even or an odd numerical relationship between reactant and product gas combining data exists, that either even or odd reactant volume data must produce corresponding values in product volume.

Session 9.

Given oxygen gas, hydrogen gas and water, be able to write three differences between these substances based upon

your own experience.

Given observations of a substance before and after heating, be able to state whether the substance is an element or a compound and support the statement.

Given the symbols for five different elements, be able to state what each of the symbols represents.

Session 10.

Given the names of sixteen substances, be able to write the molecular formulas for each substance.

Given the names of nine substance, be able to write the name of each atom present and determine the total number of atoms present in the formula.

Given a set of formulas of substances, be able to identify the element that is common among the substances.

Given a list of seven names of common substances, and their formulas, be able to write the names of the elements that are present in each substance.

Session 11.

Given the molecular formula of a substance, be able to explain the meaning of the formula in a short statement.

Given the structural formula of a compound, be able to write a short statement on what additional information is provided in the formula over the use of molecular formulas.

Be able to write an equation of identity for the number of particles in a mole.

Given the mass of three different substances and using the recommended procedure for conversion of units, be able to calculate the number of moles of each substance present.

Given the mass of a substance, be able to calculate the number of atoms present using the recommended conversion procedure.

Given the names of two substances, be able to determine the number of moles of a given particular atom in each substance.

Session 12.

Given the names of four different substances, be able to write the chemical formulas and calculate the mass of one mole of each of the substances.

Given the atomic weights of two different hypothetical elements, be able to calculate the mass of one mole of substance X formed by a combination of substance A and B.

Given the molecular formulas of five substances, be able to calculate the molecular weights for each of them.

Given a number of moles of a substance, calculate the number of grams present.

Given the mass of a substance, be able to calculate the number of moles present using the recommended conversion procedure.

Given the ratio of mass of a liter of a gas to that of a second gas, be able to calculate the molecular weight of the first gas.

Using the molecular weight that was calculated in a gas problem, be able to compare this value with a chart of elements and determine the molecular formula of the gas.

Using the molecular weight of a substance calculated in a gas problem, be able to state the relationship between this value and the value for the atomic weight of the element and also write the molecular formula of the compound.

Session 13.

Using experimentally determined data, be able to calculate the number of moles of two different substances and also be able to calculate the uncertainty in the derived values.

Using derived experimental data on the number of moles and the uncertainty for two substances, be able to compute the ratio of the substances that reacted and write a short statement on this ratio as it relates to the experiment.

Session 14.

Given data from two related experiments, be able to state the relationship between the mass of substance employed in the first experiment and the mass of substance produced in the second experiment.

Given the data from two related experiments and comparing the sums of masses involved, be able to write a short statement on the significance of the values obtained.

Given experimental data from two related experiments, be able to calculate and compare the mole ratios for the specified substances involved.

Using derived mole ratio data from two related experiments, and expressing the derived ratio in whole numbers, be able to write a short statement summarizing the mole relationships involved in the two related experiments.

Given experimental qualitative color observations from two related experiments be able to suggest a possible explanation for the two different observed colors.

Be able to write the six steps employed in conversion type problems.

Given five conversion problems, be able to write the equations of identity for each of the problems.

Given four gas volume problems, be able to calculate the number of moles of gas in each of these volumes at standard conditions.

Given the mass of two different samples of gases and their volumes at standard conditions, be able to calculate the molecular weight of each gas sample.

Be able to explain in a short statement, what is meant by standard conditions, STP and explain how this is related to Avagadro's number.

Session 15.

Given a number of molecules of reactants, in a given reaction, be able to predict the number of molecules of a product that could be formed.

Given a number of reactant molecules A with sufficient reactant molecules B to form a product, be able to determine the number of molecules of B that would be required for the reaction.

Given a common chemical reaction and the number of moles of reactant involved, be able to determine the quantity of heat energy that would be produced in the reaction.

Given a balanced chemical reaction and the volumes of gases involved, be able to calculate the number of molecules of a product produced from a given number of molecules of reactant and calculate the number of moles of product from a given number of moles of reactant.

Given a chemical reaction and the balanced equation, be able to determine the number of moles of atoms present in a given number of moles of reactant and product.

Given the names and formulas for a common chemical reaction, be able to write a balanced equation for the reaction.

Session 16.

Given a problem involving the balancing procedures in a gas reaction, be able to briefly indicate what is being done in three of the balancing steps.

Given a balanced decomposition reaction, be able to calculate the number of moles of product produced from a given number of moles of reactant.

Given a balanced decomposition reaction, be able to calculate the amount of energy which would be required to decompose a given number of moles of reactant.

Given a balanced chemical reaction, be able to calculate the amount of heat energy required to produce a stated number of moles of product.

Session 17.

Given a problem in which a number of grams of reactant A combine with a mass of reactant B to produce a mass of product C and some product D, be able to calculate the number of grams of product D produced in the reaction.

Given a problem involving reactants and products, be able to write a balanced equation for the reaction and also state the number of moles of reactant needed to produce a specified number of moles of product.

Given five statements about a common chemical reaction, be able to select the statement which is false.

Given eleven unbalanced equations, be able to balance the equations on the basis of one mole of underlined reactant.

Given the volume of a gas at a specified temperature and pressure, be able to calculate the number of molecules that are present in the volume.

Given the number of molecules present in a molar volume, be able to calculate the number of molecules present at other than standard conditions.

Be able to define molar volume and state the general relationship between the molar volumes of a gas versus liquid and also liquids versus solids.

Given the density of substance A when in solid, liquid and gaseous states, be able to determine the molar volumes of the substances in each of the three states.

Given the mass and volume of a gas at a particular temperature, be able to calculate the molecular weight of the gas.

Given qualitative observations about a gas and also its mass under certain conditions, be able to select from a set of gas formulas the formula which best accounts for the qualitative and quantitative information given.

Given a container of gas, its name, volume, temperature and pressure, be able to calculate the number of moles and determine the number of grams of the gas present.

Given a container of gas, its volume, temperature and pressure, be able to calculate the volume of the gas at standard conditions.

Session 18.

Be able to define what is meant by an ideal gas and list six characteristics that apply to ideal gases.

Be able to draw and clearly label the kinetic energy distribution curve for gases at both low and high temperatures.

Be able to define critical temperature and also what is meant by critical pressure.

Given specific changes of temperature of a gas in degrees centigrade and kelvin, be able to state in a short statement the effect that a change in temperature has on the volume of gas and be able to set up the quantitative expressions which show the effect that each change in temperature has on the initial volumes.

Be able to write a short statement describing the effect that cooling or heating has on the shape of a kinetic energy distribution curve.

Be able to write the recommended method for setting up gas conversion problems.

Be able to write an equation which shows the relationship of partial pressure to the total pressure of a gas sample.

Given a table of partial pressures and the volume of a gas collected over water, be able to set up the solution to a problem to determine the new volume.

Session 19.

Given the mass of a gas introduced into an evacuated

container of specified volume and temperature and using the ideal gas equation, be able to set up the solution of the problem to determine the pressure of the gas that is present.

Given four problems involving determination of gas volumes under varying conditions of temperature and pressure, be able to set up the solution to each problem to determine the volumes at the new conditions.

Given a water vapor reference chart, be able to set up a problem to calculate the dry volume of a gas collected over water.

Given four gas problems at different initial conditions of temperature and pressure, be able to calculate the new volumes at standard conditions.

Given the masses of gases at a specified volume and temperature, be able to calculate the total and partial pressures of the gas mixtures.

Given a gas collected over water and a vapor pressure table, be able to set up the final steps to determine the number of moles of gas that is present.

Given the mass of a gas and its formula, be able to calculate the volume of the gas under standard conditions.

Given the names, formulas and the total internal pressure of two gases in a sample, be able to determine the partial pressure of each of the gases.

Session 20.

Using the mass of one meter of magnesium ribbon employed in an experiment, be able to calculate the mass and the number of moles of magnesium when given the experimentally determined length of a magnesium strip.

Given a water vapor pressure and experimentally observed pressure of a gas collected over water, be able to calculate the partial pressure of the dry gas that was collected and the volume of the gas.

Using experimentally derived volume data for a dry known gas, be able to calculate the volume of gas that would be produced by one mole of magnesium metal.

Given that one mole of magnesium metal produces one mole of a gas, be able to set up a problem so as to calculate the volume of gas that would be produced by a specified number of moles of magnesium at the stated conditions.

Given the mass of one mole of gas collected, be able to calculate the density of the gas at standard conditions.

Given experimentally observed data, be able to calculate the uncertainties in the length of magnesium used, volume of gas collected, temperature of water, room pressure and vapor pressure of water.

Session 21.

Be able to write the symbols of the elements in one of the s_1 , s_2 , p_5 or p_6 families.

Given the molar heat values associated with a phase change of a substance, be able to calculate the amount of energy required to change a specified quantity of a substance from one phase to another.

Given a reaction involving a phase change, be able to write a thermochemical equation which expresses the change and includes the expression for the molar heat involved.

Be able to draw and label a diagram which clearly represents a model which explains the process of equilibrium involved in a phase change.

Given the heats of vaporization, condensation and the number of moles of a substance, be able to calculate the quantity of heat required in the specified phase change.

Given tables of normal boiling points and molar heats of vaporization of some pure substances, be able to examine the data provided in the tables and suggest a possible explanation for any observed patterns in the data provided.

Be able to define what is meant by, the normal boiling point of a liquid, the molar heat of melting or the molar heat of fusion.

Given three sets of liquids and a table of heats of vaporization be able to identify for each set provided, the liquid that would have the highest and lowest vapor pressures at specified temperatures.

Given the molar heat of fusion and the mass of a substance at a specified temperature, be able to calculate the energy required to fuse the given mass of the substance.

Session 22.

Given the alkali, alkaline or halogen families, be able to write the names and symbols for two of the families.

Be able to operationally define either the meaning of the term solute or solvent.

Be able to write a short statement describing the effect on boiling behavior that a solute has.

Be able to construct and clearly label a diagram which summarizes the effect that a solute has on the boiling temperature of a solution.

Be able to operationally define what is meant by the term molarity.

Given four molarity problems, be able to calculate the number of grams of solute present in each of the solutions.

Session 23.

Be able to operationally define solubility, distillation, crystallization, and precipitation.

Given the mass of a substance dissolved in a given volume of solution, be able to calculate the molarity of the solution.

Given the formula and masses of two different substances each in a different total volume of solution, be

able to calculate the molarity of each of the solutions.

Given the solution volume, molarity and formulas of solutes in the solution, be able to calculate the number of grams of the solutes present in each of the solutions.

Session 24.

Be able to state two forces, other than electrical static forces, which can act on matter and be felt at a distance.

Given an electrometer that is charged by a comb and by hair, be able to describe in a short statement the effect that such charging has on the electrometer.

Given an electrometer with charged spheres, be able to calculate the effect of charges on the distance displaced by the charged spheres.

Given a number of protons and electrons brought together be able to compute the net charge that arises when the particles are brought together.

Be able to offer an explanation why electrically neutral objects with mass are attracted to each other.

Given a series of statements which represent the changing position of fundamental particles over a period of time, be able to write a short statement which reflects your expectations that neutrons, protons and electrons are fundamental particles.

Session 25.

Given the formulas of four ionic substances dissolved in water to form conducting solutions, be able to write

dissociation equations for the four solid substances.

Given an ionic solid and the number of moles of the solid involved in a dissociation reaction, be able to calculate the number of moles of each dissociated species that is present.

Be able to explain in a short statement the meaning of square brackets that are employed around ions, radicals or other substances.

Given an ionic solid, be able to write the dissociation equation and verify the charges conserved in the dissociation.

Given an ionic solid, be able to write the dissociation equation and when given the number of grams of solid solute dissolved in a volume of solution be able to calculate the molarity of the dissociated species.

Given the volume of a dissociated substance, be able to calculate the molarity of each of the dissociated species.

Given two dissociated ionic solids in solution, be able to verify that charges are conserved in each of the dissociation reactions.

Session 26.

Given three sets of experimental data involving both precipitation and lack of precipitation of combined solutions, be able to suggest a hypothesis from the observed data that would account why precipitations were observed in some cases and not in others.

Given three precipitates from a set of experimental data, be able to propose a procedure for each of the precipitates which would test the hypothesis to confirm the precipitation of the solids.

Given the formulas of six precipitates from a table of experimental precipitations, be able to write the complete ionic equations showing the reacting species and the products formed.

Given a table of experimental observations of precipitations be able to write the net ionic equations for the identified precipitates.

Session 27.

From a set of statements involving both the absorption and the liberation of energy by an atom, be able to identify the statements which describe endothermic and exothermic processes.

Given a set of statements which describe properties and characteristics of an element, be able to select from the set the statement which does not apply.

In a short statement, be able to explain why less energy is needed to remove an electron from a neutral atom than is required to remove successive electrons from the atom.

Given an atom Z which has a nuclear charge X times that of hydrogen and also a mass that is Y times that of

hydrogen be able to calculate the number of kind of fundamental particles that are present.

Given the diameters of an atom and its nucleus, be able to compute the ratio of diameters and use this information to calculate what the average distance away from a hive a bee would be if the same scale were to apply.

Using bees and a beehive as one possible model of an atom, be able to identify the area of highest concentration of flying bees and describe the distribution which would occur.

Given an atom of an element and the masses of two of its isotopes, be able to determine the atomic number, number of protons, number of neutrons, mass number and nuclear charge for each isotope.

Given a partially completed table of information about atoms of elements, be able to complete the spaces which call for predicting either the atomic number, number of protons, electrons, neutrons and mass number.

Be able to operationally define the term isotope.

Given the mole composition of isotopes of an element, together with their mass, be able to calculate the atomic weight of the element.

Session 28.

Given two neutral noble gas atoms and their atomic

numbers, be able to calculate the ratio of the number of electrons in these atoms and compare the ratio with data about their atomic volumes, and also write a short statement on the effects of atomic size on electron-electron repulsions and electron-nuclear attraction.

Given the molar heats of vaporization of a family of elements and a table of properties of the family of elements, be able to plot the boiling points against the heats of vaporization and write a short statement summarizing the observed plot.

Using plotted information of molar heats of vaporization versus boiling points, be able to write an equation for the best line passing through the origin and other points.

Using a set of three compounds produced in a reaction of elements in families, be able to name and write the formulas for two other sets of compounds given the two new elements.

Using the information that elements in certain families form ions that have similar electron populations as inert gases, be able to write a short statement on how the ions of these families differ from the inert gases.

Given the first ionization half reaction for a metal, and that for a noble gas atom, be able to explain in a short statement how the observed energies support or fail to support the proposal that electron arrangements of inert

gases are specially stable.

Session 29.

Given two alkali metals, be able to write the equations for their reaction with water.

Given alkali-halogen reactions, be able to write a short statement on the type of bonding that occurs between these families of elements.

Given the alkali and halogen families, be able to write the symbols for each element in the families.

Be able to operationally define a covalent bond and describe in a short statement how this type of bonding relates to the halogen family of elements.

Given alkali and halogen elements, be able to write ionization half reactions for the given elements.

Be able to state two common chemical properties of alkali or halogen elements.

Given two halogen-hydrogen combinations, be able to write balanced equations for the combinations.

Given an alkali and halogen elements, be able to describe the effect of ionization on the volumes of the atoms and ions.

Session 30.

Given a reaction between a halogen element and water to form a hypohalidous acid, be able to write a similar reaction when another halogen element reacts with water.

Given a table containing either the second or third

periods of elements, be able to write the formulas for the hydrogen compounds that could be formed and also determine the hydrogen-metal ratio for each compound.

Given two alkaline-halogen reactions, be able to indicate the electron rearrangement (either gain or loss) in each kind of atom using the assumption that the atom attains noble gas electron structures.

Given a set of five formulas of compounds, be able to identify from the set the compound that is not a correct formula under normal laboratory conditions.

Given an alkali reacting with air and emitting white smoke, light and heat, be able to write an equation for the reaction and identify the composition of the smoke.

Using the formulas for an alkali oxide and alkali chloride, together with a periodic table, be able to select from a list of five ions the ion which does not have the same number of electrons as the given alkali metal.

Given an alkali-water reaction, be able to write an analogous reaction using a different alkali and water.

Using a table of formulas of some compounds of third row elements and a periodic table, be able to write the formulas for two oxides and two fluorides of four given elements.

Be able to write a short statement on the effect of increasing atomic number on the size of atoms in a period of elements.

Session 31.

Given three sets of data from a heat of reaction experiment, for each set of data be able to calculate the temperature change, amount of heat absorbed by the solution and container and the total amount of heat released in each set.

Using information derived from the heat released in three reactions, be able to calculate the amount of heat released per mole of reactant in each of the solutions and express these values as ΔH_1 , ΔH_2 and ΔH_3 .

Using the sums of ΔH_1 and ΔH_3 and comparing this value with ΔH_2 , be able to explain the observations made.

Using the values of ΔH_2 and the sum of ΔH_1 and ΔH_3 derived from experimental data, be able to calculate the percentage difference between these two values.

Be able to write net ionic equations for the three reactions involved in the reacting solutions.

Given a reactant similar to that used in one of the solutions but of different mass, be able to calculate the heat energy that would be released from the mass.

Using the derived experimental results in the heats of reaction in solution, be able to write a short statement on the effect that a change in mass would have on the heat of reaction.

Session 32.

Given a thermochemical equation, be able to rewrite the equation and express the energy using ΔH notation.

Given a fractionally balanced thermochemical equation, be able to rewrite the equation using whole number coefficients and including proper ΔH notation.

Given a set of five thermochemical reactions, be able to identify the reactions which are endothermic and those which are exothermic.

Using a standard heat of formation table, be able to calculate the heat of formation of a binary compound.

Be able to determine the energy released when a given number of moles of reactant combine to form a stated product.

Using a standard heat of formation table, be able to calculate the energy consumed when given the mass of reactant and the mass of product formed.

Using a standard heat of formation table, be able to calculate the heats of reaction for five different compounds.

Session 33.

Given a set of three reactions, be able to identify which reaction(s) would most likely be the fastest at room temperature.

Given three pairs of reactions, be able to select from each pair the reaction which would proceed the fastest.

In a short statement, be able to explain why there is a danger of explosion where large amounts of dry powdered combustible material is produced.

Be able to explain the meaning of the term activated complex.

Given two reacting gases A and B in a closed system at room temperature and pressure, be able to state the effect on the rate of reaction when the pressure, concentration and temperature conditions within the system are changed.

Be able to provide a non-book example as part of an operational definition for the meaning of the rate of reaction.

Given a potential energy diagram, be able to label the identified parts and calculate the activation energy and the ΔH of reaction.

Be able to describe three factors that can affect the rate of reaction and state how a change in these factors also changes the reaction rate.

Session 34.

Given experimental data on a rate of reaction experiment, be able to calculate the number of moles of reactant in five different reacting solution volumes.

Using experimental data from a rate of reaction experiment, be able to calculate the molarity of the reactant in five different solutions.

Given experimental data from a rate of reaction experiment, be able to explain in a short statement why it is necessary to keep the reacting volumes of the solutions at a constant volume.

Using experimentally observed reaction rate data, be able to plot and clearly label the diagram and axes for a graph of concentration versus time data.

Using plotted experimental reaction rate data, be able to summarize the observed plot and write a short statement on the observations made.

Given experimental data from a rate of reaction experiment, be able to plot and clearly label the diagram and axes for a graph of temperature versus time data.

Using plotted experimental data on the rate of reaction, be able to summarize the plotted information and explain the effect of temperature on the rate of reaction.

Using plotted experimental data on the rate of reaction as a function of concentration and temperature, be able to predict the reaction time when given a concentration and a temperature.

Session 35.

Be able to provide an example and explain what is meant by a rate determining step of a reaction.

Given an aqueous or gaseous reaction, be able to set up the mathematical expression which shows the rate of

reaction in mathematical form.

Be able to state three methods by which the pressure in a gaseous system can be increased.

Given a balanced reaction, be able to state if the reaction would proceed as written and explain your position.

Given a series of statements involving several steps in a production process, be able to rank order the steps from the slowest to the highest rate.

Be able to explain why an increase in temperature by ten degrees centigrade or kelvin will double the rate of many chemical reactions.

Given a bimolecular collision or biparticle collision in a chemical reaction, be able to state what one of the primary factors is which determines whether a reaction will occur or not.

Given an industrial process for the production of a gaseous product, be able to predict if the reaction is exothermic or endothermic, be able to calculate the ΔH of reaction and also be able to give an explanation why the reaction is conducted at the conditions stated.

APPENDIX III

A questionnaire was handed out to students one week after the last experimental session. Each questionnaire was anonymous and responses to items are contained within.

"The following is a series of statements and next to each statement you can express your feeling about the statement by circling the letter X." (X's are replaced by counts.)

	Liked or enjoyed the most		Average	Disliked or enjoyed the least	
The use of lists of objectives	9	3	1	0	0
The grading procedure used ..	3	5	2	1	2
The use of the MIVR system ..	10	2	1	0	0
Lab experiments	6	4	2	0	1
Class presentations	4	7	2	0	0
Writing laboratory reports ..	0	2	3	5	3
Chapter quizzes	0	2	4	2	5
Giving points for daily responses	6	6	1	0	0

"Use this page and any additional space needed to describe what you liked most about the course in chemistry you are taking."

a. This course had many good points. For example the use of objectives. This enabled the student to know what was expected of him (her) in the chapter or lab.

b. Another good point was the MIVR system. It is easier to answer questions and it makes you more relaxed to know that if you have an answer wrong, you can change it.

c. What I probably liked the most about this course was getting "instant feedback" during the daily responses when you were using the overheads.

d. We are learning the material completely and on a day to day basis.

e. I like the whole course in general but the use of the MIVR and objectives are especially helpful to me as a student.

f. This course stimulated my desire to learn and made me actually enjoy chemistry.

g. When you keep up with the homework, rote-memorization was unnecessary.

h. It is LOGICAL! It really makes sense, not like ... where everything was a hopeless mess and you never found out WHY! This course answers many of the WHYS, and doesn't leave you dangling for an answer.

i. It is also very math oriented, you don't just memorize lots of formulas and then plug in the values, you use your head and go through the steps yourself because you understand what you're doing instead of using abstract formulas!

j. I liked the way there was very little emphasis placed on memorizing but rather being able to use the knowledge we acquired. The opportunity of learning while you are tested by using the MIVR. The idea of being told what is expected before you are tested.

k. I like the way the course is organized and I like the way you teach it. You seem to enjoy it and let me tell you, that makes a big difference!! You show the enthusiasm and effort (and concern) that is usually lacking in teachers. I enjoyed having objectives. It not only helps us to understand what is expected of us but it also shows once again that you, too, are putting lot of work into this course. I like having responses for every assignment, it helps us to know how we are doing and gives us more of a chance to make up for a low mark.

l. The MIVR was most helpful in the course. It helped me to correct mathematical errors and enabled us to express answers precisely the way they should be.

m. I can honestly say that at least in one of the courses I am taking, I have a genuine interest and am learning something. The manner in which the material is presented with

the objectives, is easy to grasp.

n. I especially liked the daily responses. (When it was our turn to sit out back). I remembered things so much better when it was corrected immediately for errors I made on the daily responses.

o. There were some very good labs in this course they taught me a lot and gave me a much better knowledge in the use of some lab. equipment.

p. I like the presentations on the overhead with the charts and everything.

q. Labs were helpful because they exhibited clearly what you were studying in class: Therefore you can understand the factual material better.

r. Lab experiments = chemistry in action.

s. Teacher is very interesting.

t. Objectives almost encouraged you to do your homework.

u. Lectures (use of overhead, slides, etc.)

"Use this page and any additional space needed to describe what you disliked most about the course in chemistry you are taking."

a. Should allow say 2 days for a lab report.

b. Should have overheads for all students.

c. Should get new Chem books, old ones are falling apart.

d. Quizzes.

e. I dislike having to turn in lab reports the day after the lab, otherwise it was really good.

f. Doing experiments where you only, after its done, find out what was supposed to happen.

g. Having to do lab reports (I dislike them but that doesn't mean I think they should be eliminated).

h. Lab reports.

"Write out as many items as you possibly can think of that could be used to improve the course."

a. More space, less students.

b. Lab reports should be done by the class as a whole, thus getting more students involved in the not only actual lab, but also giving the student a better conception of purpose of the lab. It will also bring out more ideas and opinions about the lab, thus giving the student more information on the lab.

c. Chapter quizzes should be given only if the student elects to have it. The teacher can decide how much a student knows about the information given in the chapter through daily responses and oral participation in class.

d. Grades should not be given. Often grades scare students away from learning, many times a student chokes before a quiz or test and although he (she) knows the information, he (she) receives a failing grade which in turn makes the student apathetic toward the course.

e. "Lab reports" should be of the simplest possible structure if required but preferably, not required at all.

f. In order for students to learn the intricacies of experimentation and observation, one or two "major experiments" should always be designed, executed and written up by each student or small group of students per year.

g. More visual aid material, charts, diagrams, etc.

h. More class presentations and daily responses.

g. An expanded library of chemistry books.

i. Overhead projectors for all students.

j. Two days on lab reports

k. I think that you should have MIVR's for everyone because without them the grade is just reduced to a percentage on the score sheet.

l. Hold prelabs, not writing out lab reports, no chapter tests.

