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A.N.

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CHAPTER 1

Introduction

Present-day science teachers have felt a growing concern for the apparent lack of motivation or interest displayed by students taking their courses. Many feel that this was due to the varying backgrounds and abilities of those placed in their classrooms. Others believe that there are many moderating variables aside from learning ability which may affect student success. B.L. Thompson (1975), in a study on 1 310 boys and 1 073 girls of a comprehensive modern school system in England, uncovered that, in general, attitudes towards both school and teachers deteriorated as pupils progressed through the system. Jackson and Lahaderne (1967) and J.C.G. Lunn (1969), in independent studies completed previously, had correlated student attitudes to their school environment, to achievement, and to social class while Berk (1970), replicating Lunn's study in North America, found no significant correlation between these factors and attitude. It would seem apparent that social class and environment change with each country, if not within each school, and would be a difficult variable to control. In the search for moderators which would help the teacher predict student interest and success in science courses this study was conducted to investigate the effects that a competency-based pedagogy in chemistry had on student cognitive and affective behaviour and to unveil some moderating variables which would enable the teacher to diagnose the type of approach each student in his course would require.

One such teaching strategy which could alleviate social class and the effects of school environment should be the Keller approach (Keller, 1968). In this study a competency-based unit in chemistry was developed along the lines of Keller's personalized system of instruction, or P.S.I., in which a student progresses at his own pace, must exhibit mastery of a unit before proceeding to the next unit, and positive motivation is reinforced by the teacher or proctor, who acts as a manager of the learning resources available.

The P.S.I. is not completely an individualized instruction strategy since no two students may complete the given unit in the same way, though this is a possibility. Each student is allowed to use as much of the available resources and personnel as required and group discussions, while completing his task, are allowed. The system is personalized in every sense of the word. By allowing the student to complete the prescribed program on an almost individual basis, the environmental determinant, that is peer group pressure, should be effectively eliminated. By involving the student in his own evaluation and providing him with instant feedback as to his progress, his epistemic motivation should be enhanced. The results should be enhanced cognitive and affective behaviour towards the course. McCormack (1973, p. 59) pointed out that "the drive for personal adequacy has significant implications for teachers. Since students inherently are driven to become as personally adequate as possible, specific motivation procedures are unnecessary in the teaching process. Instead of coercing and coaxing, the teacher should try to discover the underlying motives already operating within the student, and suitable experiences to facilitate ongoing growth processes".

Bruner (1960) stressed the importance of providing appropriate learning strategies for cognitive and affective development. Piaget (Ginsberg and Opper, 1969) indicated that it is possible to accelerate intellectual development through types of learning by suitable environmental stimuli. Frank E. Williams, in his Models for Encouraging Creativity in the Classroom by Integrating Cognitive-Affective Behaviour (1969, p.12) produced a model which attempted to integrate teacher behaviour interacting with curriculum to influence student cognitive and affective functioning. Eighteen teaching styles or strategies are listed as a means, through subject matter content, towards an end for fostering eight thinking and feeling pupil behaviours. Implicit in this model is the need for maximizing teacher-student interaction. P.S.I. strategy optimizes this aspect of learning. P.S.I., as did William's model, specifies terminal behaviours or competencies for the student to aspire. Harrisberger (Sherman, 1974, p. 158) provided a rather astonishing list of feedback from P.S.I. including reinforcement of positive attitude towards the course, high motivation, and increased performance. Born and Whelan (Sherman, 1974, p. 202) urgently indicated that replication of studies on cause and effects of competency-based pedagogy should be done before the above stated results are incorporated into a theory of learning.

In conclusion it has been shown that one aspect of concern for student success in his educational endeavours has been to find and identify moderators which could be used to select those students who would require additional proctoring or different teaching strategies. The make-up of the P.S.I. program seems to indicate such a strategy which could encompass the needs of all levels of motivation. Models developed independently showed a need for linking teaching strategies to learning abilities. Theoretically speaking, P.S.I. would seem to be a useful innovation in the field of education.

Chapter two will deal, indetail, with the problem researched in this report. Chapter three will provide a summative analysis of the many findings that have been reported on all aspects of P.S.I. research and attitude changes. Chapter four will describe the operational definitions of the variables used in this study and the hypotheses investigated. Chapter five will provide a description of procedure. Chapter six will deal, in detail, with the instrumentation used for this study and chapters seven and eight will present the data derived and interpretations.

CHAPTER 2

The Problem Statement

The competency-based pedagogy used in this study consisted of a number of adjunct study guides (Langdon, 1973, p. 61),each keyed to the prescribed text for the course,consisting of a list of behavioural objectives for the unit at hand, a description of the tasks involved to achieve these objectives, and a supplementary section consisting of alternative materials for that unit (see Appendix A). Each adjunct study guide was backed up by a short competencies test which provided the student with several alternatives. If the student succeeded at a 90% level he was allowed to continue on to the next unit. If he obtained less than 90% but still retained a passing grade, the student consulted his teacher who advised him (after checking comprehension of test questions,completion of assigned tasks,etc.) as to his possible course of action before being allowed to attempt an alternate form of the same test. If the student had failed, he consulted the teacher as to the source of his failure and,after appropriate action, repeated the unit before reassessment (see Appendix B).

This study attempted to determine if, overall, this approach to the teaching of an abstract subject,such as chemistry, provided for a more positive attitude towards science in general and a more improved cognitive performance.

Several moderating variables were included in relation to this study, the number of courses or previous history in science and the level of intellectual development. The level of intellectual development,as proposed by Piaget (Herron,1975), concerned a relatively recent discovery that students, who should be at the formal operations level in their approach to learning in their final year of secondary schooling,have been found to be, in some cases, at the concrete or postconcrete operational level (Lawson and Renner, 1974). Since most final year chemistry content is at the formal level, the implications for curriculum design and teaching strategies could be of great importance.

The problem statements were then formulated as follows:

(a) Will the introduction of a competency-based approach to the teaching of chemistry result in improved motivation in students towards the subject as indicated by improved cognitive and affective behaviour?

(b) Is there a relationship between success in a competency-based course and previous history in the subject or the level of intellectual development?

The implications of this study can readily be seen if one looks at the context in which this research was undertaken. Most teachers are assigned to large class populations in which the student intellectual ability is spread across a broad spectrum. If competency-based pedagogy provided an approach to the acquisition of 'knowledge' which allows each student a basic amount of attention while providing the weaker pupil with the chance at extra attention, the end-product should be greatly enhanced. Teaching is not meant, at the high school level, to be a method of dissemination of facts but is mainly provided for social and psychological development. In science, the main goal is to build in a student confidence in himself and the ability to function individually in problem-solving whatever the problem. The delineation of moderating variables should help teachers and administrators understand the complex field of learning and would improve the quality of education.

"The likelihood of the student putting his knowledge to use is influenced by his attitude for or against the subject; things disliked have a way of being forgotten. One objective towards which to strive is that of having the student leave your influence with as favourable an attitude towards your subject as possible. In this way you will help to maximize the possibility that he will remember what he has been taught, and will willingly learn more about what he has been taught" (Mager, 1968, p. 11).

P.S.I. strategy seemed to provided the necessary positive reinforcers and aversive stimuli which would not only ensure maximum probability of success but would also ensure that the student will enjoy his studies. As Mager points out above, the development and maintenance of a healthy attitude towards a subject being taught reinforces the student's desire to perform cognitively and, hopefully, affectively. P.S.I. strategy seemed also to provide the teacher with the chance to make sure that the students with a lower intellectual development obtain extra guidance they seemed to need. A look at previous research into all aspects of P.S.I. was undertaken to ensure a good empirical and theoretical precedence for the continuation of this study.

CHAPTER 3

Related Research

Since P.S.I. strategy consists of many different aspects of learning theory, any attempt to find related research must first have included studies dealing with those different aspects. With this in mind, a search of the literature into the effects of behavioural objectives was undertaken. Also included were attitude research, individualized instruction, and research into various moderators. Finally any research into the "why" of P.S.I. was explored.

Behavioural Objectives

Since behavioural objectives form an integral part of competency-based pedagogy, a search of the literature for justification for their inclusion was undertaken. It was found that there are two major streams of thought concerning the use of behavioural objectives. They are usually classified as behaviourists versus humanists.

Advocates for the use of behavioural objectives in teaching strategies (Bloom, 1956; Krathwohl, 1964; Mager, 1968; Harbeck, 1970) state that teaching is actually behaviour modification intended to shape desired response patterns through conditioning by proper positive and negative reinforcement. Teaching is something done to the learner by adjusting external conditions. Providing objectives to students will set the minimum prerequisite competencies and, at the same time, allow for proper management of the learning environment.

The case presented against the presentation of behavioural objectives (McCormack, 1973, p. 57) has been seen as one of tunnel vision. "Hyperplanning in terms of behaviour may cause inflexible structuring of learning sequences. The teaching moment well known to the seasoned instructor may be overlooked by overly·mechanical pedagogues adhering rigidly to heirarchies of competencies specifications. Teacher's spontaneity is undermined".

Most empirical studies have concluded that behavioural objectives act as orienting and organizing guides to study and facilitate learning (Anderson,DeMelo,Szabo,and Toth,1975; Herron,1971; Huck and Long,1973; Jenkins,1974; Merrill,1974), yet Olsen (1973) found evidence to suggest that behavioural objectives have no effect at all.

In the context of competency-based pedagogy, behavioural objectives are seen as the orienting and organizing influence needed to inspire not restrict the student. Research tends to agree that their inclusion into a teaching strategy is at least not detrimental and at the most a factor for improvement. The P.S.I. inclusion of behavioural objectives is therefore justified and need not be tampered with. A look at the theory of operant conditioning may explain why.

A definition of operant conditioning was very well put forth by J. Michael and L. Meyerson in their <u>A Behavioural Approach to Counseling and Guidance</u> (Cummings and Scott,1973, p. 5). "Whereas for reflexes and conditioned reflexes the event of critical explanatory importance is the eliciting stimulus preceding the response,for a large class of non-reflex behaviour the critical events are the environmental consequences of the behaviour. Such behaviour can be said to 'operate' on the environment, in contrast to behaviour which is 'respondent' to prior eliciting stimuli".

The kinds of stimulus events which are consequences of acts can be divided into two major groups in terms of their effects on operant behaviour: (i) positive reinforcers which are defined by the observation that the behaviour which preceded them has a higher probability of occurrence under similar conditions in the future and (ii) negative reinforcers which are defined by the observation that behaviour which preceded their removal is more likely to occur under similar conditions in the future.

The inclusion of behavioural objectives can therefore be seen as introducing a factor which allows the student to increase his chances of success (positive reinforcers) and removes anxiety and peer group pressure in their ability to provide explicit guidance in the course of their studies (negative reinforcers or aversive stimuli). Thus the adjunct study guide included in the P.S.I. strategy borrowed heavily from operant conditioning, something which should be greatly increased in teaching approaches.

Attitude and Individualized Instruction

Since individualized instruction is inherently a part of P.S.I. strategy, several aspects of this type of learning were investigated. A special interest in related attitudinal studies was conducted.

Attitude studies have always depended on the instrumentation used and several inventories have been developed which serve this purpose. Most use semantic differential testing or Likert scales (Blair and Kershner, 1975). When research into the effects of teaching strategies on student attitude is investigated, one finds that most have dealt with attitude towards the teacher, the room, the course, and everything else in sight. Very few were done with the overall discipline in mind and its interaction with behaviour. One definitive study by Shock (1973) concluded that affective and cognitive behaviour in an individualized program have no relationship. A person can like the subject being taught but will still fail his examinations. Littlefield (1975), on the other hand, found that high achievers, after completion of 34 individualized units of instruction, developed more positive attitudes towards science but he was unable to uncover any moderating variables. Charen (1966) and Johnson and Ryan (1974) both found that open-ended inductive approaches to science helped develop a more positive attitude towards the subject. Students reported that the approach made them feel like real scientists. Starr (1972), using Invitations to Inquiry from the Biological Science Curriculum Study Program (Schwab, 1963) found in his study that attitude was not affected by the inquiry approach. The contradictory findings can possibly be explained by the different procedural systems used in these studies. In Charen's and Johnson and Ryan's studies students were self-paced while Starr presented each of the inquiry situations orally to his class. Since P.S.I. involves the student in self-pacing it would seem that those findings of Charen and Johnson and Ryan in which attitude was positively affected could apply. A look at this aspect follows.

Contingency-based Pedagogy and Attitude

Jerstedt (1976), comparing a Keller approach to the traditional lecture approach, found that those who were subjected to P.S.I. developed a more positive attitude towards the subject. What was interesting was the disclosure that those in the lecture program scored significantly better on the multiple-choice examination but poorer on the written essay. He concluded that this was due to the fact that the students undergoing the competency-based strategy were provided with behavioural objectives which allowed for better study habits and learning when open-ended questions were presented. This finding was reinforced by Taylor (1975) and Humphrey and Townsend (1974). Competency-based learning seemed to improve work habits due to the student's perception that this method of learning required more work than usual. Along with better study habits, the approach instilled a drive which provided for self-generating reinforcement.

Moderating Variables and Continguency-based Pedagogy

Though research seemed to reveal that P.S.I. was as good or better than traditional or conventional teaching strategies, the reasons for P.S.I. success was not as clear. Ward (1976) concluded from his study that class size did not interact with attitude towards the subject matter. But it is significant to note that he did find that class size and achievement were related and that achievement had an interaction with attitude. It would seem that there was an indirect relationship between class size and attitude. Since P.S.I. allows for varying class sizes, Ward's findings imply that the size of a class in P.S.I. is one of the moderators of this strategy's success.

Linder and Whitehurst (1973), investigating whether P.S.I. may introduce a novelty effect and thus be a factor in its own success, found no such variable. Maron and Tyler (1976), investigating whether the factor of self-paying may moderate the P.S.I. success, found that it was the operational procedures and not the self-pacing factor which may be variables in P.S.I. success. Taylor (1975), in her investigations, found indications to show that average and poor students did better than was expected because of matching their relative work input into the course to their perception of the amount of work required. P.S.I. operational procedures require more involvement then usual and this, she hypothesized, may be a factor in P.S.I. success. Taylor also concluded that P.S.I. acted as operant conditioning reinforcers which support favourable habits and tactics towards better learning.

Newman, et al (1972), trying to link student background to success in P.S.I., determined that students doing badly usually had poor grades in previous science subjects undertaken. This may be linked to levels of intellectual development. Piagetian intellectual development has never been investigated as a moderator in P.S.I. research. Evidence does indicate that a given class will usually contain concrete, postconcrete and formal operational levels of students at the senior high school level. Chiappetta (1976) in his A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level summarized the general conclusion thus: the level or percent of students at the concrete level from junior high school to college seems to range from zero to roughly 80%. "The research reviewed indicates that the majority of young adults function at the concrete operational level and not at the formal operational level in understanding a great deal of the science subject matter taught at the secondary and college level" (Chiappetta, 1976, p. 259). Since research done on P.S.I. has invariably been targeted at post-secondary populations and the subject matter being used is usually at the formal operations level, this aspect of the problem seemed to be of great importance.

Summary of Related Research

Empirical evidence seems to indicate that P.S.I. was at least as effective as conventional methods in both the cognitive and affective domains. Most research done has been targeted at post-secondary students. Research seemed to show that there was no reason to expect different results at the secondary level. As to the question "why does P.S.I. work?", indications are that operational procedures used by P.S.I. strategy may be an important factor. The relation to operant behavioural theory and P.S.I.'s inherent role as possible reinforcement of the desire to perform was proposed. The link to levels of intellectual development was not sufficiently researched and only reinforced the inclusion of this important factor and its relationship to previous history in science.

Since no single factor or variable functions to the exclusion of others, the review of related research pointed out the incomplete nature of P.S.I. research in terms of moderating variables. Studies at the secondary level were especially insufficient; therefore, replication at this level is justifiable. The link between P.S.I. strategy and Piagetian intellectual development had not yet been investigated and this aspect of the study seemed of great importance. With these points in mind, operational definitions of variables were formulated and resulting research hypotheses were predicted.

CHAPTER 4

Operational Definitions of the Variables

Dependent Variables

Cognitive behaviour: the ability to complete, successfully, a series of multiple-choice questions based on the behavioural objectives of a given unit.

Affective behaviour: the numerical value obtained by a student on the Scientific Attitude Inventory (Moore, 1969).

Moderating Variables

Levels of intellectual development: the score obtained by a student on a series of Piagetian tasks as used by Lawson and Renner (1974). A score of between 0-8 is to be considered concrete operational thought. A score of between 9-11 is to be considered postconcrete operational and between 12-13 is to be considered formal operational (Inhelder and Piaget, 1958).

Previous history in science subjects: the number of courses in any science subject completed by a student at the secondary school level previous to entering the program under study.

Independent Variables

Competencies approach: a pedagogy involving the use of an adjunct study guide consisting of a list of behavioural objectives and task assignments, followed by a competency test based upon these objectives which must be completed at a 90% level to progress to the next unit (Keller, 1968) (see Appendix A), usually termed personalized instruction.

Traditional approach: a pedagogy consisting of lecture-discussion sessions of intact classes in which several class tests and a final unit test are administered to the class as a whole with 40% of the class mark and 60% of the unit test mark used to produce a score for the overall unit (50% being a pass). For the purpose of this study,the unit test markonly was considered.

Hypotheses

With these operational definitions in mind, a series of hypotheses were formulated:

H_1: The competencies approach to teaching high school senior chemistry will result in a higher cognitive behaviour in students when compared to traditional methods.

H_2: The competencies approach to teaching high school senior chemistry will result in a higher affective behaviour towards science as a whole in students when compared to the traditional approach.

H_3:The level of intellectual development of a student will determine whether this student will improve his cognitive and affective behaviour no matter if the competencies approach or traditional approach is used.

H_4: Previous history of science subjects will determine whether this student will improve his cognitive and affective behaviour no matter if the competencies approach or the traditional approach is used.

Empirical evidence for H_1 and H_2 was found in Johnson and Ryan's study (1974). They concluded that an individualized approach to teaching with the use of behavioural objectives was not detrimental to attitudinal development.Previous studies by Charen (1966) and Jernstedt (1976) reinforced their findings. Taylor (1975) and Humphrey and Townsend (1974) revealed that competency-based pedagogy improved both affective and cognitive behaviour in students when compared to a traditional approach.

Since the application of P.S.I. strategy involves both the use of competency-based pedagogy and the choice of individualized instruction, it was concluded that the findings of these researchers could be applied to P.S.I. strategy and should improve cognitive and affective behaviour of the students.

Theoretical evidence for H_1 and H_2 was found in the writings of Mager (1968), McCormack (1973), Harbeck (1970) and Gagné (1970). All agreed that motivation and attitude were related. Motivation was thought to be intimately associated with cognitive functioning. Because of the use of operant behaviourism in the theoretical design of P.S.I., it followed that P.S.I. would reinforce and improve the motivational aspect of the student's performance and thus improve his cognitive and affective behaviour.

Empirical evidence for H_3 was determined in a study by Lawson and Renner (1974). Among their findings was the apparent lack of formal operational students at the secondary level. An analysis of course content of senior science courses revealed a large percentage of the content required abstract reasoning. It was postulated that students not at the formal level would have great difficulty in performing when abstract logic was required. This would then directly affect their cognitive and affective behaviour by way of lower marks and increased anxiety. Their findings were reinforced by Ball and Sayre (1975) who found a significant relationship between scholastic success of chemistry students and their level of intellectual development. Students functioning at the formal operational level performed better than those functioning at a concrete level ($p < 0,01$). Since scholastic success is closely related to student self-perception and related peer-group pressure, formal operational students should perform better both cognitively and affectively.

Theoretical evidence for H_3 was determined from a study of Piagetian theory (Inhendler and Piaget, 1958) in which the levels of intellectual development were delineated and the ability of the student associated with each level was described. Based upon empirical data, Piaget constructed a model of intellectual development that culminated in what he called formal operational thought. Lawson and Renner (1974) hypothesized that some students were between formal and concrete operational thought. These students were described as postconcrete students. Since the age at which a person achieves formal thinking differs according to many factors, including environmental, no distinct age can be chosen at which to introduce curricula based on logical reasoning. The student not at the formal operational level has been found to be unable to theoretically cope with abstract tasks such as are usually the bulk of senior science courses, especially chemistry. It follows that formal operational students should be able to perform better cognitively and that resulting self-achievement improve their affective behaviour in the course.

Empirical evidence to support H_4 was not found, although a study by Newman, et al (1972) did reveal that the student with poor academic records in science usually did poorly or dropped out of the P.S.I. program. If there were a relationship between poor grades in previous science courses and the amount of science courses taken, then this might provide some precedence for the hypothese. This aspect of the study, therefore, was completely new in the research literature, as far as could be determined.

Theoretical evidence for H_4 seemed to stem from the author's experience as a teacher of science for several years. It would seem that a knowledge of the terminology and ways of approaching problems scientifically that can be developed through partaking in science courses would govern how a student functions cognitively and affectively. The more courses in science one takes, the better prepared one is to cope with new science material. The number of science courses could also give the teacher some indication of the attitude the student has towards science.

With operational definitions of variables described and hypotheses formulated, procedural techniques were then itemized and instrumentation required for this study was amassed.

CHAPTER 5

Procedure

Population and Sample

The population from which subjects were selected for this study consisted of 2000 English-speaking secondary students with wide socio-economic backgrounds. The comprehensive high school which serves this population is situated in a middle-class suburb in the South Shore region of the city of Montreal, Canada and draws its clientele from as far away as Lacolle, a small rural community 30 kilometers to the south on the United States border. The courses offered at this secondary school range from vocational to pure academic.

The subjects selected had all previously completed the first year of a two year chemistry course based on the first 17 chapters of the D.C. Heath version of the Chemstudy program (O'Connor et al,1973). All students had followed a science stream since entering secondary school. The sampling procedure was restricted to intact groups of secondary five students preselected by school scheduling computers. A total of 81 students were available. Four classes were randomly assigned to either the traditional or personalized system of instruction previously defined. The resulting division placed 37 students in the traditional classes and 44 students in the P.S.I. classes. The age and sex breakdown for each treatment can be seen in Table 1.

Research Design

The P.S.I. group (N= 44) received the previously described program which differed from the traditional group in that the regular class tests were used as competency tests. The traditional group (N= 37) and the P.S.I. group both received a multiple-choice test, based on the behavioural

Table 1

Descriptive Breakdown of Treatment Groups

			Sex	
Group	Mean Age	S.D.	Male	Female
Traditional	16,1	0,6	29	8
P.S.I.	16,0	0,6	24	20

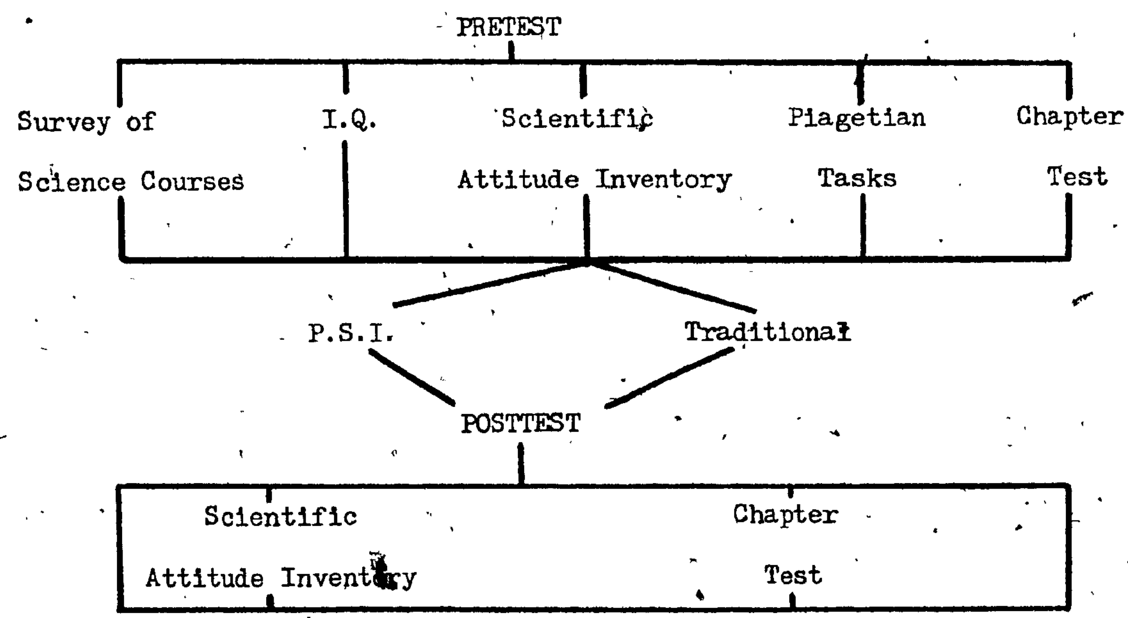

Figure 1. Crossbreak of the Research Design.

objectives of the course section being taught.

In addition, both groups submitted to a series of pretests as a regular part of their orientation to the program. These tests, described more fully later (see Chapter 6), were:

1. Otis quick-scoring mental ability test, gamma version (Harcourt, Brace and World, 1954)

This test data was used as a test for homogeneity of variance and as a covariant during initial analysis.

2. Scientific attitude inventory, form A (Moore, 1969)

3. Chapter test, form A (see Appendix E)

Each group was posttested with form B of the Scientific Attitude Inventory and the chapter test previously mentioned (see Appendix F).

To measure the level of Piagetian intellectual development, each student was asked to complete four Piagetian tasks (see Chapter 6). Finally, each student was asked to complete a descriptive statistics form to determine their age, sex, and previous history of science courses.

Since randomization of samples were restricted to intact groups, a quasi-experimental nonequivalent control group design was drawn up as set forth by Campbell and Stanley (1963, p. 47)(see Fig. 1)

0	X	0
0		0

In January, 1977 the two previously described groups were pretested and then allowed to engage in a regular unit in chemistry for five 45 minute periods a week for one month. Each group was treated as previously described. After completion of the unit, both classes were posttested for cognitive and affective changes. As explained by Campbell and Stanley

(1963, p. 48), this design controlled for internal validity fairly satisfactorily if group means and standard deviations were similar on the pretest. The use of a control group, which in this study were the students undergoing a traditional teaching strategy, insured against mistaking effects of history, pretesting, maturation, and instrumentation. In addition, the use of the Otis Mental Ability Test as a covariant when analysis of posttest results was carried out further insured internal validity.

Since the length of time of this study was one month, history was controlled as well as any possible Hawthorne effect. As will be seen later, time developed into an important and critical factor in the interpretation of the results of this study.

Since intellectual development and previous history in science were studied as moderating effects, it was hoped that any possible interaction effects between selection and history or selection and testing would be measurable. This, plus the fact that all groups were taught by the same teacher and in the same room, hopefully minimized any regression effects.

Since intact groups were used which did not disrupt the normal atmosphere and the unit taught was a regularly scheduled unit for that time slot, it was hoped that external validity was established. The short time of the study should have prevented any reactive effects to treatment.

CHAPTER 6

Instrumentation

Descriptive Statistics

Included in the descriptive statistics data collected from each student was a request to list all previously taken science courses at the secondary school level begining at level one. This data was then coded as 1 for having taken 3 courses or less in science and 2 for having taken 4 courses or more. The students were thus classified because the spread of courses taken among the subjects ranging from one course to eight varied significantly. The division represented the median of the data. Along with the data, age and sex was also solicited.

Inferential Statistics

Otis Quick-scoring Mental Ability Test (Gamma)

This test purports to measure indirectly the mental ability of students and present them in the form of "deviation-I.Q.'s". The I.Q. found is termed a gamma I.Q. and has been shown to be less variable than ordinary I.Q. The use of the English language is of paramount importance in completing this test and, thus, all non-Anglophone students were not included in this study.

The reliability coefficient, corrected by the Spearman-Brown formula, for grade 11 was reported as 0,91. The validity of the test, determined by a biserial coefficient of correlation between the item and the total score in the test, was measured at + 0,61 (Harcourt, Brace and World, 1954).

The Otis test was administered to all subjects at the commencement of the study and served two major purposes. First was to test for homogeneity of variance and second was to use the resulting data as a covariant in the analysis of variance.

The Scientific Attitude Inventory (Moore, 1969)

The attitude items assessed by the Scientific Attitude Inventory were based upon the concerns of science educators for the objectives of science teaching as reported by Moore (1969, pp. 53-54). Sixty statements concerning positive and negative attitudes towards science were presented to the student who was asked to rate each on a Likert scale ranging from strongly agree to strongly disagree. The weights assigned to each response ranged from a 3 for a positive attitude answer of strongly agree to 0 for a negative attitude answer of strongly agree. The tests were scored by computer using an adapted Fortran program (see Appendix C). A series of values were produced for a total score for the intellectual attitudes for each student and a total score for emotional attitude towards science for each student. Both scores were evaluated in pre- and posttest data. Two forms of the inventory were used, each differing only in the order in which the questions were presented. The reported test-retest reliability coefficient obtained by Moore was 0,934.

Piagetian tasks

A series of four tasks, designed to measure the level of intellectual development, were adopted from the Lawson and Renner (1974) scheme. Each student observed the teacher performing a demonstration and then proceeded to answer questions posed on an answer sheet(see Appendix D). Scoring was done by hand according to procedures set forth by Hooper and Sigel (1968) in their Logical Thinking in Children.

(1) The conservation of mass task: (scored at a maximum of 2 points)

"After the subject is satisfied that two balls of clay weigh the same, one ball is transformed into a 'sausage' shape. The subject is then questioned about the relative weights of the clay objects" (Lawson and Renner, 1974, p. 548). This task was reported to measure only concrete operational thought.

(2) The conservation of volume task: (scored at a maximum 3 points)

"This task tested for understanding of the fact that water displacement is a function of the volume of the object, not its mass, i.e. two metal cylinders of equal volume but different masses will displace equal amounts of water" (Lawson and Renner, 1974, p. 548). In this study a ball of plasticine replaced the two metal cylinders and the shape of the ball was changed before questions on displacement were asked.

This task was reported by Piaget (Inhelder and Piaget, 1958) to measure formal operations but was later found to require only a high degree of concrete operational thought which was termed postconcrete.

(3) The separation of variables task: (scored at a maximum of 4 points)

"This task tested the subject's ability to control and exclude irrelevant variables. Using a simple pendulum, the subject was given the problem of determining what variables affect the period. Since the only causal factor is the length of the string, the factors of the weight of the bob, angle of drop, and force or push must be excluded" (Lawson and Renner, 1974, p. 548). This task also measured postconcrete operations.

(4) Equilibrium in the balance: (scored at a maximum of 4 points)

"This task, using a balance beam and hanging weights, tests the subject's ability to balance various combinations of weights at various locations on the beam, e.g. given a 10 unit weight 7 units from the fulcrum, the subject must predict the proper location of a 7 unit weight to achieve a balance. Successful completion of this task implied an understanding of inverse proportions" (Lawson and Renner, 1974, p. 548) (formal thought).

Total scores of 0-8 were considered concrete operational, scores of

9-11 were classified as postconcrete and 12-13 were classified as formal operational. Lawson and Renner found that, as Piaget had predicted (Inhendler and Piaget, 1958), intellectual development was best tested in a field relevant to the subject's field of interest, thus the great deal of science content found in these tests. However, they did report that the results obtained from the tests correlated somewhat with College Entrance Examination Board Achievement examinations in science, mathematics and English showing that the tests were relatively content free.

These tasks were submitted to intact groups of subjects, a search of the literature revealed that, using similar tasks Mealing (cited in Rowell and Hoffman, 1975, p. 157) reported the following correlations between scores obtained and mental age: (i) $r = 0,89$, $n = 57$ and (ii) $r = 0,80$, $n = 54$. These high correlations between performance on Piagetian tasks and mental age allowed Rowell and Hoffman (1975) to use this finding to determine the effectiveness in using groups testing, as was done in this study. They found that, in an attempt to validate group tests for distinguishing between formal operational and concrete operational students using the simple pendulum test, the product moment correlation coefficient, r, was 0,92, $n = 186$. Thus group testing was shown to be effective. Though the group method of administration lost most of the sensitivity inherent in the original clinical approach, Rowell and Hoffman do state that their study did show the validity and practical reliability of group administration and rapid assessment of Piagetian-type problems indicating development.

<u>The chapter test</u> (teacher-made)

Each group was subjected to two forms of this test, which measured the level of cognitive awareness of material presented in the unit taught, based upon the behavioural objectives of each task sheet (see Appendices E and F). The behavioural objectives, used in the adjunct study guide (see Appendix A), were derived from the teacher's guide to the course and were described as an accurate list of objectives for this section of the course by many teachers contacted who did, in fact, teach this program. Because of the origin of the objectives and the general agreement among the previously-mentioned 'judges', content validity of this instrument is claimed.

In evaluating this test for construct validity, each test item was keyed to a specific behavioural objective in the adjunct study guide. All 6 items were found to be representative of the various objectives and tasks in the adjunct study guide provided to all students in P.S.I. (see Appendices E and F).

To further insure construct validity, an item analysis of each test item against the total score for the test was performed using the top and bottom 25% of the students who wrote the test.

The resulting point-biserial correlation coefficients were then t-tested for significance according to Bruning and Kintz (1968, p. 166), (see Appendix G). Of the items, only item 2 of this test (see Appendix E) failed to significantly descriminate between the top and bottom 25% of the subjects. It was felt that this test item should be kept so that there would have been at least one item on the test which each student could complete correctly. This was done for pedagogical reasons. As a result of the item analysis, construct validity is claimed.

The consistency and stability of the test can be seen by both the previously mentioned item analysis and by the Kuder-Richardson formula-21 for the coefficient of equivalence. An $r_{K.R.21}$ of 0.58 was derived using the top and bottom 25% of the subjects submitting to the test.The value derived shows a test which is relatively reliable in its function. The value shown may be attributed to the varying levels of difficulty among the test items.

Overall, the chapter test,used to measure pre- and post-cognitive behaviour of students subjected to the study of energy effects in chemical reactions, was shown to be both valid and reliable.

CHAPTER 7

Statistical Treatment and Results

Statistical Treatment

All statistical treatments in this study were performed on a C.D.C. 6000 computer using S.P.S.S. (Bent et al,1975). The Otis-Lennon Mental Abilities Test was hand-scored as was the teacher-made test. As stated previously (see Chapter 6), the Scientific Attitude Inventory was scored by using a modified version of the fortran program provided by Moore (1969). The Piagetian intellectual development test was hand-scored.

Since intact groups were used preventing actual randomization, analysis of covariance, with the gamma I.Q. and appropriate pretest as covariants, was used to test the 4 hypotheses put forth in Chapter 4. Since the use of covariant analysis requires equal variance before treatment, an analysis for homogeneity of variance was run using the gamma I.Q. as the criterion. This produced an F_{max} test as described in Winer (1962, p. 92).

In order to determine any nesting effects, the data acquired was coded in terms of high and low using the median as the determining criterion. The resulting coding allowed for a series of 2 x 2 Chi-square tests using treatment against posttest scores controlling firstly for low cognitive and affective pretest scores and then controlling for high cognitive and affective pretest scores. This was then repeated but with the introduction of intellectual development and previous history in science separately and then collectively.

Finally, to determine the role of intellectual development in this study, a graph was drawn to depict cognitive means on pretest as opposed to posttest means, as related to level of intellectual operations, for both treatment groups.

Results

In testing for homogeneity of variance, using gamma I.Q. data, an F_{max} (df 2,40)= 1,029, $p > 0{,}01$, was determined which showed that the two treatment groups were homogeneous in variance allowing for the use of covariant analysis (see Table 2).

Descriptive data concerning previous history in science, as depicted in Table 3, revealed that the traditional group contained 17 students with 3 courses or less and 20 students with 4 courses or more while the P.S.I. group had 14 and 30 students repectively. The data indicated that the traditional students were evenly mixed with regards to previous history in science courses while the P.S.I. group contained twice as many students with 4 courses in science or more than 3 courses in science or less. This only confirmed the necessity for the F_{max} test previously described.

Results of the Piagetian intellectual development tests, shown in Table 4, revealed that both treatment groups contained approximately even distribution of concrete to postconcrete to formal operational students.

A summary of pre- and posttest data for the cognitive and affective behaviour is depicted in Table 5. The search of the means revealed that, for attitude, there was little change between pre- and posttest behaviour but, cognitively, there was a dramatic increase for both groups. However, the series of analyses of covariance tests run revealed no significant differences between groups in all respect. Previous science history did not significantly affect cognitive and affective behaviour but, Piagetian intellectual development proved to have an overall effect on cognitive behaviour for both groups [F (df 2,68) = 4,214, $p < 0{,}018$] (see Table 6).

In order to determine if any nesting effects were present and to investigate further the role of intellectual development, all appropriate data was coded as follows: using the median score for both the pre- and posttest of the attitude survey and the cognitive test, students were assigned the number 1 for being below the median and the number 2 for being above the median (Appendix H). The resulting 2 x 2 Chi-square tests produced no significant results, as shown in tables 7 and 8. This was due, in part, to the low cell populations when moderators were included.

Finally, using breakdown data of pre- and posttest cognitive scores as related to intellectual development (Appendices I and J), graphs were drawn to provide a pictorial trend to cognitive means (see Figure 2 and 3). These graphs revealed that formal operational students in both groups performed better on both pre- and posttests cognitively. It was interesting to note that, in both treatment groups, the concrete operational students improved more than the postconcrete students almost equaling the formal operational students on the posttest.

Table 2

F-Maximum Test for Homogeneity of Variance[a]

Using Otis-Lennon Mental I.Q.

Treatment	Cases	Mean[b]	S.D.	Min.	Max.	S.E.	Variance
Traditional	34	115,7	9,1	91,0	132	1,6	83,62
P.S.I.	43	111,4	9,0	91,0	132	1,4	81,28

[a]Maximum variance/minimum variance = 1,029 ($p > 0,01$).

[b]General population mean for 16 year olds is 101.

Table 3

Breakdown of Previous Science Course per Treatment

On Basis of Descriptive Data

Treatment	3 courses or less	4 courses or more	N
Traditional	17	20	37
P.S.I.	14	30	44

Note. Numbers in Table= numbers of students.

Table 4

Breakdown of Piagetian Intellectual Development

Per Treatment on Basis of Task Tests Results

Treatment	1-concrete	2-postconcrete	3-formal	N
Traditional	4	26	7	37
P.S.I.	5	29	10	44

Note. Numbers in Table = numbers of students.

Table 5

Summary per Treatment of Test Data[a]

In Affective and Cognitive Behaviour

Test	Traditional[b] Mean	S.D.	S.E.	P.S.I.[c] Mean	S.D.	S.E.
			Emotional attitude			
Pretest	59,8	8,2	1,4	62,0	6,5	0,98
Posttest	60,1	8,1	1,3	61,4	7,4	1,1
			Intellectual attitude			
Pretest	66,1	6,6	1,1	65,1	8,2	1,2
Posttest	66,3	8,9	1,5	65,8	8,5	1,3
			Cognitive			
Pretest	27,1	20,5	3,4	38,6	19,6	3,0
Posttest	79,3	19,8	3,3	76,1	19,5	2,9

[a]Means in Table under attitude = scores on Scientific Attitude Inventory (maximum score is 90), cognitive means are percentage correct on teacher-made test.

[b]n = 33

[c]n = 44

Table 6

Analysis of Covariance

Posttest Cognitive Results by Treatment,

Previous History in Science and Intellectual Development

With Pretest Cognitive Results and I.Q.

Source of Variance	df	M.S.	F.
Covariates	2	875,2	2,492
Precognitive	1	1157,3	3,296
I.Q.	1	672,4	1,915
Main effects	4	766,9	2,184
Treatment	1	61,7	0,176
History	1	261,3	0,744
Int. dev.	2	1479,6	4,214**
2-Way interaction	5	368,9	1,051
Treatment-history	2	1029,6	2,932
Treatment-int. dev.	2	353,8	1,008
History-int. dev.	2	186,4	0,531
3-Way interaction	1	39,6	0,113
Residual	68	351,1	
Total	80	382,2	

** $p < 0,018$

Table 7

2 x 2 Chi-square[a]

Treatment by Postcognitive Results

Controlled for Low Pretest Scores

	Postcognitive scores	
	Low[b]	High[c]
Traditional	6	12
P.S.I.	7	17

Corrected χ^2 (df 1) = 0,00232, $p > 0,05$.

[a]Sample chi-square test showing nonsignificance.

[b]Number of students maintaining a low score from pre- to posttest.

[c]Number of students improving from a low pretest score to a high posttest score.

Table 8

2 x 2 Chi-square

Treatment by Postcognitive Results

Controlling for Low Pretest Scores

And Postconcrete Intellectual Development

	Postcognitive Scores	
Treatment	Low[a]	High[b]
Traditional	4	9
P.S.I.	6	10

Corrected χ^2 (*df* 1) = 0,00018, $p > 0,05$.

Note. Only those students who were at postconcrete operational levels were used in this chi-square test.

[a]Number of students maintaining a low score from pre- to posttest.

[b]Number of students improving to a high posttest score from a low pretest score.

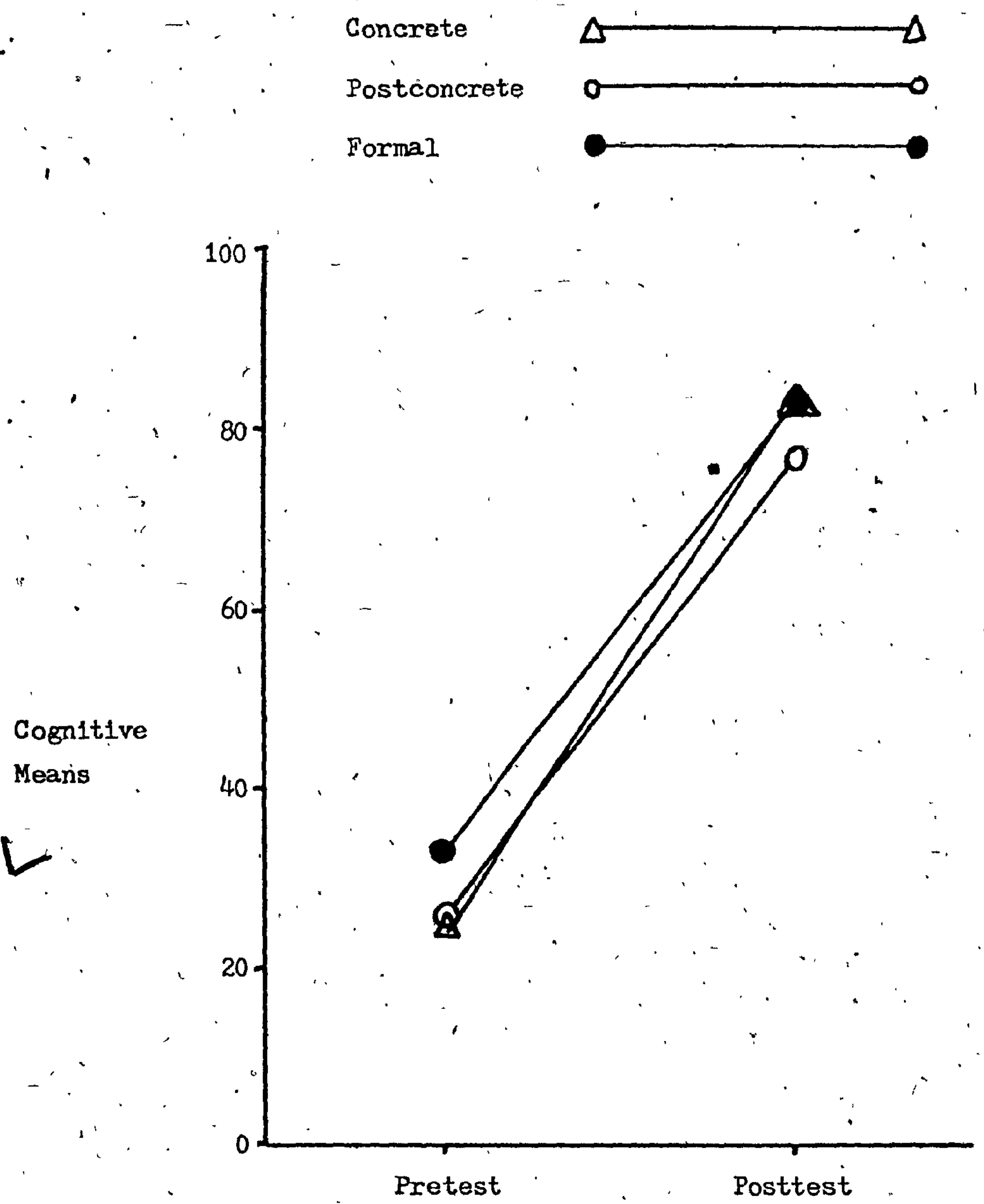

Figure 2. Cognitive mean trends for the traditional group as related to intellectual development.

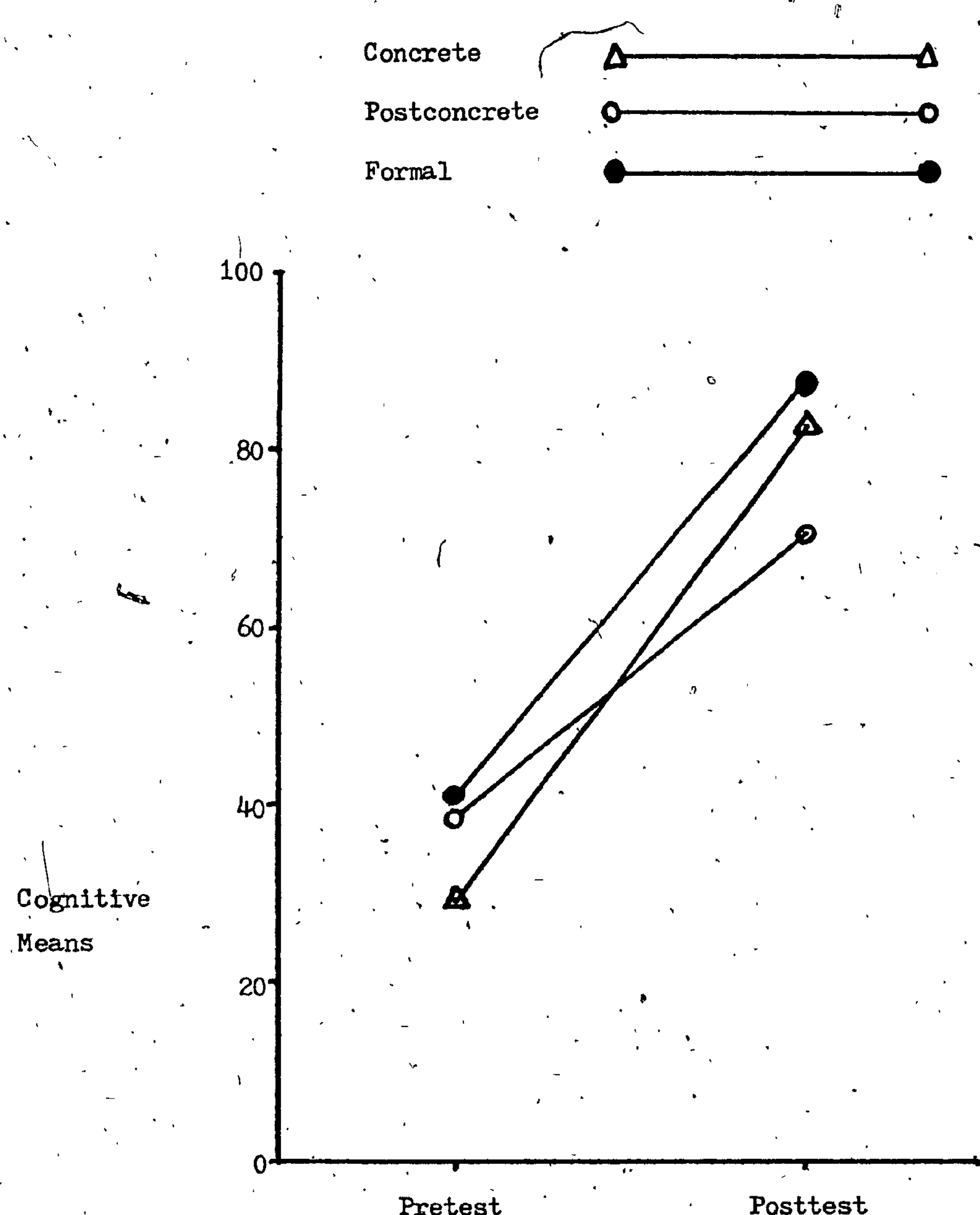

Figure 3. Cognitive mean trends for the P.S.I. group as related to intellectual development.

CHAPTER 8

Discussion

The results of the covariant analysis indicated a rejection of Hypotheses 1 and 2 (see Chapter 4, p. 16). With respect to overall effects of treatment on cognitive and affective behaviour, several factors may have come into play. The first and most important seemed to have been the time factor. Most of the related research reviewed indicated a study time-span of at least one semester. This study covered approximately one month which is the equivalent of 1/4 semester. It would seem that the students may not have spent enough time with P.S.I. to alter their cognitive and, especially, affective behaviour. The study did show that P.S.I. was not detrimental to learning in the short term. Students maintained their level of attitude towards science and improved cognitively equally to those in the traditional group.

With respect to attitude towards science, most students involved in this study chose chemistry voluntarily and had a high attitude towards the subject before treatment. If nothing else, one might have expected a regression effect among the P.S.I. students but this did not materialize. The fact that P.S.I. strategy did not produce negative attitudes towards the subject was seen as a positive factor.

The breakdown of intellectual development (see Table 4) supported the findings of Lawson and Renner (1974) in that most students were found to be at a postconcrete operational level. While intellectual development did not differentiate between the traditional and P.S.I. groups, it would seem that formal operational students did function more effectively in an abstract science such as chemistry. This again supported Lawson and Renner and, thus, the findings failed to reject Hypothesis 3 partially. Formal operational students functed better in the cognitive sense only (see Table 6). Attitudinal behaviour did not seem to be effected by intellectual development, in the short term. The lack of any significance in the interaction between intellectual development and attitude in covariant analysis seemed to suggest that attitudes toward a course had no relation to the level of comprehension. This seemed to support the findings of Schock (1973) and Johnson and Ryan (1974).

Figures 2 and 3, while indicating the apparent success of formal operational subjects over subjects of other levels, also show that the concrete subjects seemed to have surpassed the postconcrete students cognitively on the posttest. This may have been due to a maturation effect of the subject matter; that is, thosesubjects seemed to have become at least postconcrete in their intellectual level of operations.

It seemed that further research into levels of intellectual development and teaching strategies were suggested. One possibility would be a long term study with concrete operational students to determine whether P.S.I. causes more students to be raised to a formal level than other strategies. If this hypothesis were substantiated, the use of P.S.I. would be shown to be cost-beneficial.

Past experience in science courses, as indicated by the number of science courses taken proved to be, in the short term, ineffective in identifying which students will improve cognitive and affective behaviour. Covariant analysis showed no significant effect of this factor in any way with treatment. This would seem to refute the arguments put forth by many educators that prerequisite courses in junior science is a necessity before acceptance of students into senior science. Research into this aspect could be extended to a long term study of interactions with reading levels and mathematical abilities.

Overall, P.S.I. strategy was shown to be at least as effective as the conventional lecture-discussion approach in the short term. Since very few studies at the secondary level have been undertaken, further studies on the effectiveness both cognitively and affectively over the long term should be undertaken perhaps by the use of restriction to those students at the concrete level only or with student with a medium to low attitude towards science. This would suggest studies at the junior high school level.

As mentioned before, P.S.I. may be shown, through additional investigation, to be a most cost-beneficial teaching strategy. Of increasing usefulness in education today, especially with restrictive budgeting by governments, is a criterion called cost-benefit. Cost-benefit is another way of asking what was provided by the teacher and what was produced, that is, outcomes relating to documented needs. If a course or learning experience is found to be 50 % effective according to the selected criteria, teaching strategies can be devised to improve the effectiveness. If P.S.I. is more successful in raising the effectiveness of the learning experience than other strategies, then it can be said to be more cost-beneficial. Implicit in this approach to educational analysis would be the cost outlay in the implementation of a particular strategy in relation to the benefits derived. Cost-benefit is not the same as cost-efficient. Achievement of efficiency without benefits is not a great accomplishment. A look at P.S.I. operational strategy shows a very efficient method of providing students with suitable learning environments while at the same time making maximum use of a teacher's time. What has yet to be shown is whether P.S.I. strategy is more cost-beneficial then other strategies.

Studies at the post-secondary level indicate that student achievement rate is higher (Sherman, 1974, p. 49). At the secondary level, as this study seems to indicate, P.S.I. has been shown to be as effective as a traditional strategy. Further studies with respect to its ability to improve affective and cognitive behaviour and possibly intellectual development were recommended. Cost-beneficial or not, P.S.I. trategy has proved to be an important addition to the arsenal of strategies available to teachers who are concerned with humanizing the educational experiences of their students.

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APPENDIX A: SAMPLE P.S.I. UNIT

Chemistry: Unit Eleven

Task One: (time limit-3 periods)

Upon completion of this task you will:

(A) given a list of events or objects, be able to indicate relative potential energies present in each.

(B) given an equation, in either words or symbols, including the energy term, rewrite the equation using ΔH notation.

(C) given the amount of energy absorbed or released when a given mass of a substance reacts, calculate ΔH for the reaction.

(D) given the ΔH for a chemical reaction, determine if the reaction is exothermic or endothermic.

(E) given the energy term or ΔH for a chemical reaction, calculate how much energy will be released or absorbed when X grams of one reactant are consumed.

(F) given the energy term or ΔH for a chemical reaction, calculate the mass (or number of moles) of any of the substances in the reaction that would correspond to a given number of kilojoules of energy.

TASK:

READ: text sections 11-1 to 11-3 pg. 192-198.

DO: problems 1 thru 9, pg. 204.

CHECK: your answers with the answer sheet available from your teacher.

SUPPLEMENTARY MATERIALS:

1. Text: Chemistry-experimental foundations (Cotton-Lynch)

   READ: text section 9-1 to 9-1.3, pp. 201-204.

   Do: problems 1 thru 9, pp. 220-221.

2. <u>Text</u>: Chemistry-an investigative approach (Parry et al.)

   <u>READ</u>: text section 12-1,12-2, pp. 281-284.

   <u>DO:</u> questions 1-13, pg. 299.

3. <u>Filmstrip</u>: Heat and temperature-molecular energy (F.S. 541)

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task One (Form A)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. For each of the following indicate which contains more stored potential energy?

   (A) a pile of coal or a heap of ashes.

   (B) a box of rose fertilzer or a rose bush.

   (C) a liter of gasoline or a milliter of gasoline.

   (D) a new battery or a battery in use.

2. Identify each of the following equations as either exothermic or endothermic.

   (A) $2Au(s) + 3/2\ O_2(g) \longrightarrow Au_2O_3(s) + 8,4\ kJ$

   (B) $Si(g) + 2Cl(g) - 611,9\ kJ \longrightarrow SiCl_4(l)$

   (C) $NH_4NO_3(s) \longrightarrow NH_4NO_3(aq) \quad \Delta H = +28,6\ kJ$

   (D) $Li(s) + 1/2\ H_2(g) \longrightarrow LiH(s) \quad \Delta H = -21,6\ kJ$

   (E) $H_2SO_4(l) - 75,6\ kJ \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$

3. Rewrite each of the following equations using ΔH notation.

   (A) $2Au(s) + 3/2\ O_2(g) \longrightarrow Au_2O_3(s) + 8,4\ kJ$

   (B) $Si(g) + 2Cl(g) \longrightarrow SiCl_4(l) + 611,9\ kJ$

   (C) $H_2SO_4(l) - 75,6\ kJ \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$

   (D) $2B(s) + 3/2\ H_2(g) + 31,5\ kJ \longrightarrow B_2H_6(g)$

4. If 3,48 kJ of heat is required to change 3,60 grams of $NaHSO_4(s)$ to $SO_3(g)$, determine the ΔH for this reaction.

$$2NaHSO_4(s) \longrightarrow Na_2SO_4(s) + H_2O(g) + SO_3(g)$$

5. How many kilojoules of heat energy is required to decompose 15,9 g. of $LiH(s)$ into $Li(s)$ and $H_2(g)$ at 25°C and 101 kPa. ?

$$Li(s) + 1/2\ H_2(g) \longrightarrow LiH(s) \qquad \Delta H = -90,7 \text{ kJ}$$

6. Given $C_2H_2(g) + 5/2\ O_2(g) \longrightarrow 2CO_2(g) + H_2O(g) \qquad \Delta H = -1260,4 \text{ kJ}$

Determine how many grams of acetylene (C_2H_2) will burn to supply 6302 kJ. of heat.

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task One (Form B)

Answer all questions on the answer sheet provided.

When completed, see your teacher for scoring.

1. Identify each of the following equations as either exothermic or endothermic.

   (A) $C_8H_{18}(l) + 12\ 1/2\ O_2(g) - 5472,6\ kJ \rightarrow 8CO_2(g) + 9H_2O(g)$

   (B) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 92,4\ kJ$

   (C) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g) - 180,6\ kJ$

   (D) $AgNO_3(s) + 22,8\ kJ \rightarrow Ag^+(aq) + NO_3^-(aq)$

2. Rewrite the four equations in question 1 using proper ΔH notation.

3. For each of the following examples indicate which contains more E_p.

   (A) A candle lit or an unlit candle.

   (B) A new flash cube or a used flash cube.

   (C) A block of ice or a bucket of water.

   (D) A rocket at rest or a rocket in flight.

4. Given: $C_2H_2(g) + 5/2\ O_2(g) \rightarrow 2CO_2(g) + H_2O(g) \quad \Delta H = -1260,4\ kJ$

   Determine how many grams of acetylene (C_2H_2) will burn to supply 9453 kJ of heat.

5. If 10,44 kJ of heat is required to change 10,8 g of $NaHSO_4(s)$ to $SO_3(g)$, determine the ΔH for the $NaHSO_4$ in this reaction.

   $$2NaHSO_4(s) \rightarrow Na_2SO_4(s) + H_2O(s) + SO_3(g)$$

6. How many kilojoules of heat is required to decompose 31,8 g of $LiH(s)$ into $Li(s)$ and $H_2(g)$ at 25°C and 101 kPa. ?

$$Li(s) + 1/2\ H_2(g) \longrightarrow LiH(s) \qquad \Delta H = +90,7\ kJ$$

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Task Two: (time limit- 2 periods)

Upon completion of this task you will:

(A) given the mass of water in a calorimeter and the change in temperature, be able to calculate the number of joules absorbed by the water.

(B) be able to write net ionic equations for chemical reactions including the energy term as ΔH.

(C) given the ΔH of several intermediate reactions, be able to determine the net ΔH for the overall reaction.

TASK:

READ: exp. 26, pp. 66-67 in your lab manual and prepare a suitable data table.

PERFORM: exp. 26, pp. 66-67 (Heat of Reaction) with a partner.

COMPLETE: the processing the data for this experiment and compare your findings with the sample data available from your teacher.

SUPPLEMENTARY MATERIAL:

1. Text: Chemistry: book I (Nuffield A-Level)

   READ: Topic 7- Energy changes and bonding, pp. 163-168.

   PERFORM: Exp. 7.2a (Evaluation of an Enthalpy Change) pp. 175-176.

   Answer: all questions asked in your lab notebook and check your answers with those available from your teacher.

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Two (Form A)

Answer all questions on the answer sheet provided.

When completed, see your teacher for scoring.

1. In an experiment similar to exp. 26, 5,61 g of potassium hydroxide (KOH) were dissolved in 200 ml of water. The temperature of the water rose 7,0 °C. The molar heat of solution for KOH, in joules per mole, is?

2. The heat of reaction for the formation of nitric oxide (NO) form its element is +90,7 kj/mole.

$$1/2\ N_2(g) + 1/2\ O_2(g) \longrightarrow NO(g) \qquad \Delta H = +90,7\ kJ/mol$$

How many grams of NO(g) can be formed by the expenditure of 453,5 kJ of energy? (assume the molar mass of N = 14,0; O = 16,0)

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Two (Form B)

Answer all questions on the answer sheet provided.

When completed, see your teacher for scoring.

1. The heat of reaction for the formation of nitrogen dioxide (NO_2) from its elements is +34,02 kJ/mole.

$$1/2\ N_2(g) + O_2(g) \longrightarrow NO_2(g) \qquad \Delta H = +34{,}02\ \text{kJ/mol}$$

How many grams of $NO_2(g)$ can be formed by the expenditure of 170,1 kJ of energy? (assume the molar mass of N = 14,0 and O = 16,0)

2. In an experiment similar to exp. 26, 2,39 g of LiOH were dissolved in 150 ml of water. The temperature of the water rose 5,0 °C. The molar heat of solution for LiOH, in joules per mole, is?
(assume the molar mass of Li = 6,9 ; O = 16,0 ; H = 1,0)

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Task Three: (time limit- 3 periods)

Upon completion of this task:

(A) you will, using values of ΔH given in Table 11-2 (revised), be able to calculate the heat of reaction for reactions involving two or more reactions from the table.

(B) you will be able to combine two or more equations for which ΔH is given to obtain the equation for another chemical reaction and determine the ΔH for that reaction.

TASK:

READ: text section 11-4, pp. 198-201 of your book.

DO: exercises 11-1 to 11-5 in the chapter and problems 10,11,20,21 (easy), 13,14,16,19,22,23,24 (medium), 12,15,17,18,25 (hard).

CHECK: your answers with the answer sheet available from your teacher.

SUPPLEMENTARY MATERIAL:

1. Text: Chemistry: experimental foundations (Parry et al)

   Read: text section 9-1.5, pp. 206-209.

   DO: problems 11-14, pg. 221.

2. Text: Chemistry: student book I (A Level-Nuffield)

   Read: Topic 7- The use of standard heats of formation, pp. 176-177.

   DO: problems 3 and 7, pp. 200-201.

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Three (Form A)

Answer all questions on the answer sheet provided.

When completed, see your teacher for scoring.

1. Ammonia (NH_3) burns in air to produce nitrogen dioxide and water according to the following equation:

   $NH_3(g) + 7/4\ O_2(g) \longrightarrow NO_2(g) + 3/2\ H_2O(g) \quad \Delta H = ?$

   Use the information in the following equations to determine the ΔH for the above reaction.

   $NH_3(g) \longrightarrow 1/2\ N_2(g) + 3/2\ H_2(g) \quad \Delta H = +46{,}2$ kJ

   $1/2\ N_2(g) + O_2(g) \longrightarrow NO_2(g) \quad \Delta H = +34{,}02$ kJ

   $H_2 + 1/2\ O_2(g) \longrightarrow H_2O(g) \quad \Delta H = -242{,}76$ kJ

2. Given the following three equations, determine the ΔH for the fourth equation.

   $S(s) + 2\ O_2(g) + H_2(g) \longrightarrow H_2SO_4(l) \quad \Delta H = -814{,}8$ kJ

   $SO_3(g) \longrightarrow S(s) + 3/2\ O_2(g) \quad \Delta H = +396{,}5$ kJ

   $H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l) \quad \Delta H = -286{,}9$ kJ

   $SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(l) \quad \Delta H = ?$

3. Calculate the heat of reaction for the following equation:

   $C_3H_7COOH(l) + 5\ O_2(g) \longrightarrow 4\ CO_2(g) + 4\ H_2O(l) \quad \Delta H = ?$

(continuation of question 3)

given the following:

$$4\ C(s) + 4\ H_2(g) + O_2(g) \longrightarrow C_3H_7COOH(l) \qquad \Delta H = -\ 524{,}58\ kJ$$

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -\ 394{,}80\ kJ$$

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286{,}86\ kJ$$

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Three (Form B)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. Acetylene (C_2H_2) burns in the presence of air to form carbon dioxide and water according to the following equation:

$$C_2H_2(g) + 2\ 1/2\ O_2(g) \longrightarrow 2CO_2(g) + H_2O(g) \qquad \Delta H = ?$$

Using the information below, determine the ΔH for the burning of C_2H_2.

$$2C(s) + H_2(g) \longrightarrow C_2H_2(g) \qquad \Delta H = +\ 227{,}6\ kJ$$

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -\ 395{,}2\ kJ$$

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -\ 242{,}8\ kJ$$

2. Given the following two equations:

$$H_2(g) + O_2(g) \longrightarrow H_2O_2(l) + 188{,}3\ kJ$$

$$H_2O_2(l) \longrightarrow H_2O(l) + 1/2\ O_2(g) + 98{,}6\ kJ$$

determine the ΔH for:

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l)$$

3. Given the following three equations:

$$Ca(s) + 2H_2O(l) \longrightarrow Ca^{2+}(aq) + 2OH^-(aq) + H_2(g) + 432{,}6\ kJ$$

$$CaO(s) + H_2O(l) \longrightarrow Ca^{2+}(aq) + 2OH^-(aq) + 81{,}9\ kJ$$

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l) + 286{,}9\ kJ$$

determine the ΔH for:

$$Ca(s) + 1/2\ O_2(g) \longrightarrow CaO(s) \qquad \Delta H = ?$$

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Task Four: (time limit- 2 periods)

Upon completion of this task you will:

(A) combine two or more equations for which ΔH is given to obtain the equation for another chemical reaction and thus determine the ΔH for this reaction.

(B) be able to calculate the ΔH for a given reaction given the mass of the reactants and change in temperature of the water in the calorimeter.

TASK:

READ: exp. 27, pg. 68 of the lab manual and prepare a suitable data table.

PERFORM: exp. 27, pg. 68 (Heat of Reaction).

COMPLETE: processing the data for this experiment and compare your findings with the sample data available from your teacher.

SUPPLEMENTARY MATERIAL:

1. Text: Chemistry: student book I (A-Level Nuffield)

   Read: Topic 7 - Indirect methods for obtaining standard heats of formation, pp. 173-175.

   Perform: exp. 7,2b (Evaluation of an enthalpy change indirectly), pp. 175-176.

   Answer: all questions asked in your lab notebook and check your answers with your teacher.

Chemistry:Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Four (Form A)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. When magnesium burns, it does so according to the following equations:

$$Mg(s) + 1/2\ O_2(g) \longrightarrow MgO(s) \qquad \Delta H = -\ 604,8\ kJ$$

If the conversion of 1 gram of matter into energy produces $9,07 \times 10^{10}$ kJ, how much mass is theoretically converted in the burning of one mole of magnesium? (Mg = 24,3 g/mole)

(A) $6,67 \times 10^{-10}$ g
(B) $6,67 \times 10^{-8}$ g
(C) $1,50 \times 10^{8}$ g
(D) $6,67 \times 10^{-9}$ g
(E) $1,50 \times 10^{-8}$ g

2. Given the following equations:

$$6C(s) + 3H_2(g) \longrightarrow C_6H_6(g) \qquad \Delta H = +\ 83,2\ kJ$$

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -\ 394,8\ kJ$$

$$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -242,8\ kJ$$

calculate the H for the following:

$$C_6H_6(g) + 7\ 1/2\ O_2(g) \longrightarrow 6CO_2(g) + 3\ H_2O(g) \qquad \Delta H = ?$$

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Four (Form B)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. When cadmium metal burns, it does so according to the following:

   $$Cd(s) + 1/2\ O_2(g) \longrightarrow CdO(s) \qquad \Delta H = -261,7\ kJ$$

   If the conversion of 1 gram of matter to energy produces $9,07 \times 10^{10}$ kJ, how much mass was theoretically converted in the burning of 1 mole of cadmium metal? (Cd = 112,4 g/mole)

2. Acetic acid or vinegar (CH_3COOH) burns to form carbon monoxide, carbon dioxide and water according to the following equation:

   $$3CH_3COOH(l) + 11/2\ O_2(g) \longrightarrow 5CO_2(g) + CO(g) + 6H_2O(l) \quad \Delta H = ?$$

   determine the ΔH for the above reaction using the following information:

   $$CH_3COOH(l) \longrightarrow 2C(s) + 2H_2(g) + O_2(g) \qquad \Delta H = +488,9\ kJ$$

   $$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -394,8\ kJ$$

   $$C(s) + 1/2\ O_2(g) \longrightarrow CO(g) \qquad \Delta H = -110,8\ kJ$$

   $$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286,9\ kJ$$

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Task Five: (time limit- 1 period)

Upon completion of this task you will:

(A) state what is meant by the phrase "conservation of energy" giving illustrations (either physical or chemical) which show that this principle is valid.

(B) name and describe, using diagrams as needed, the three types of motion exhibited by molecules.

(C) outline the events and associated energy changes that occur on the molecular level as a substance is either heated or cooled. This heating or cooling will involve phase changes.

TASK:

READ: text section 11-5,11-6, pp. 201-203.

DO: problems 26-32.

CHECK: your answers with the answer sheet available from your teacher.

Library Source:

Film: Vibrations of molecules and molecular motion.

(complete film guide available from teacher)

SUPPLEMENTARY MATERIAL:

1. Text: Chemistry (Kavanah, Robbins, and Oberkreiser)

READ: The motion of particles, pp. 279-280.

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Five (Form A)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. Describe what is meant by the phrase "conservation of energy" giving examples and illustrations (either physical or chemical) which shows this principle to be valid.
2. Name and describe, using diagrams if needed, the three types of motion exhibited by molecules.
3. When gaseous chlorine is heated from 25°C to 50°C, the energy absorbed is largely expressed as which one of the following?

   (A) an increase in E_p,

   (B) an increase in vibrational energy,

   (C) an increase in rotational energy,

   (D) an increase in translational energy,

   (E) an increase in ionization energy.

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Competency Test for Task Five (Form B)

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

1. Which molecule has the greatest ability to store energy as it is heated, carbon tetrachloride (CCl_4) gas or argon (Ar) gas ? Explain your answer indicating the kinds of motion by which each of these molecules can store energy.

2. When solid NaCl (sodium chloride) is heated from 500°C to 808°C, the substance will reach its melting point. The energy applied to the system before melting begins is stored as:

   (A) an increase in E_p,

   (B) an increase in vibrational energy,

   (C) an increase in rotational energy,

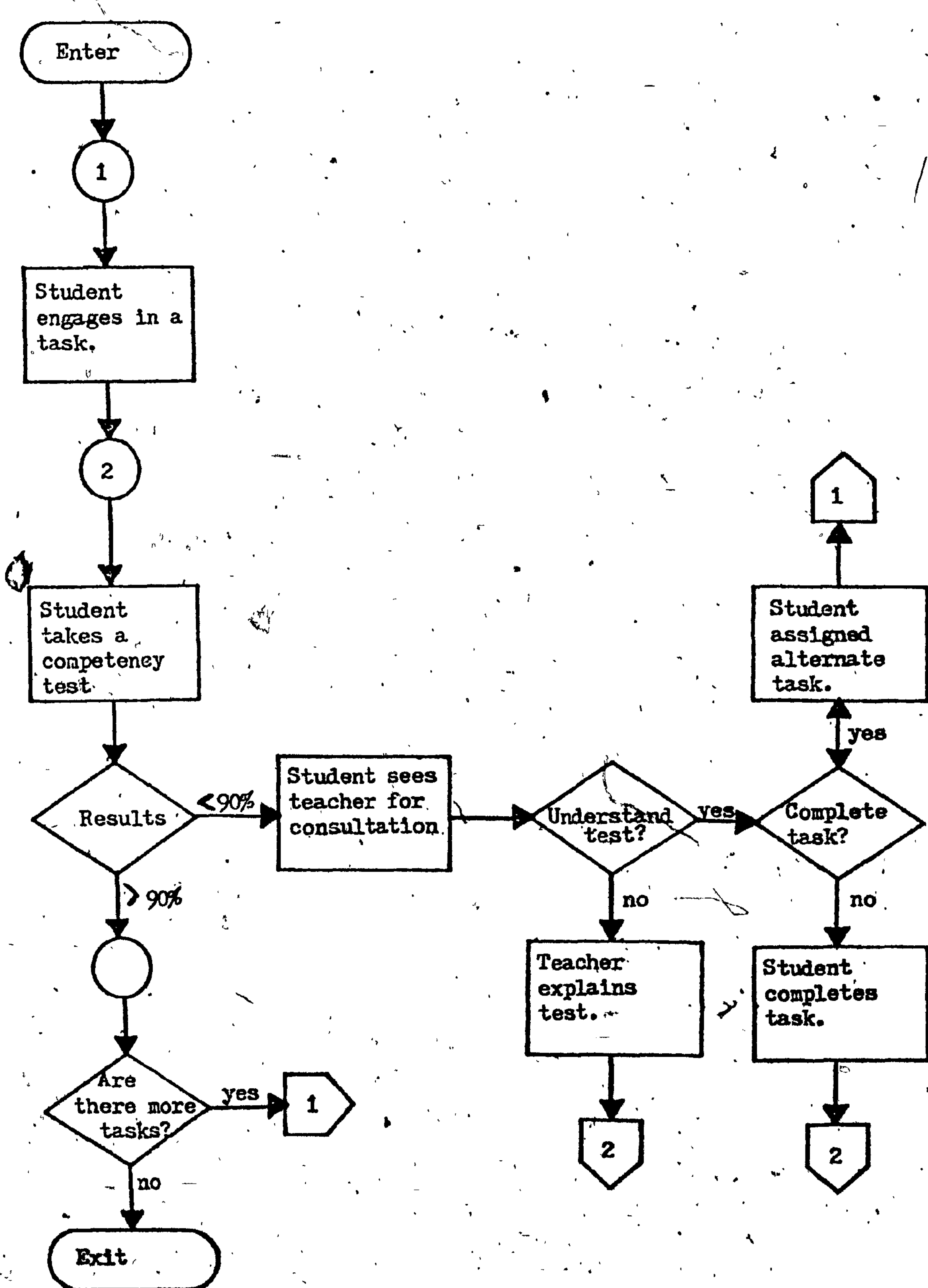
   (D) an increase in translational energy,

   (E) an increase in ionization energy.

3. Using an example, show why the concept of "conservation of energy" is valid.

APPENDIX B: FLOW DIAGRAM FOR COMPETENCY-BASED PEDAGOGY

Flow diagram for competency-based pedagogy



9

APPENDIX C: MODIFIED COMPUTER PROGRAM FOR SCORING SCIENTIFIC ATTITUDE INVENTORY

Modified computer program for scoring the Scientific Attitude Inventory taken from Moore (1969).

```
C       PROGRAM SCAT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C       SCIENTIFIC ATTITUDE INVENTORY FOR PSI RESEARCH
C       NO. 1-87 ARE PRETEST RESULTS AND 88-174 ARE POSTTEST SCORES
C       N21 SCORES INTELLECTUAL ATTITUDE, N22 SCORES EMOTIONAL ATT.
C       N23 IS THE TOTAL SCORE OF TYPE A AND TYPE B STATEMENTS
C       N23 IS THE TOTAL ATTITUDINAL SCORE FOR THE INVENTORY PER STUDENT
        DIMENSION I(1), J(30), K(30)
     22 FORMAT(I7,5X,60I1)
     23 FORMAT(I7,2X,22I3,1X,I4)
    333 READ(5,22)I(1),J(26),K(6),K(7),K(11),K(12),J(16),J(1),K(13),K(21),
       /J(2),K(8),K(1),K(22),K(16),J(6),K(2),J(21),J(11),J(7),K(26),K(27),
       /K(3),J(3),K(17),J(12),J(13),J(8),J(22),J(9),J(23),K(23),J(17),J(18
       /),J(19),K(28),K(24),J(14),K(14),K(9),J(24),K(18),J(15),K(10),K(19)
       /,J(27),K(4),J(20),J(25),J(28),K(20),K(15),J(10),J(4),K(5),J(29),J(
       /5),K(29),K(25),K(30),J(30)
        IF (EOF(5))600,30
     30 DO 3 M = 1,30,1
        IF (J(M).EQ.0)   J(M) = 15
        IF (J(M).EQ.1)   J(M) = 30
        IF (J(M).EQ.2)   J(M) = 20
        IF (J(M).EQ.3)   J(M) = 10
        IF (J(M).EQ.4)   J(M) = 00
        IF (J(M).EQ.5)   J(M) = 15
        IF (K(M).EQ.0)   K(M) = 15
        IF (K(M).EQ.1)   K(M) = 00
        IF (K(M).EQ.2)   K(M) = 10
        IF (K(M).EQ.3)   K(M) = 20
        IF (K(M).EQ.4)   K(M) = 30
      3 IF (K(M).EQ.5)   K(M) = 15
        N1 = J(1)+J(2)+J(3)+J(4)+J(5)
        N2 = J(6)+J(7)+J(8)+J(9)+J(10)
        N3 = J(11)+J(12)+J(13)+J(14)+J(15)
```

```
      N4 = J(16)+J(17)+J(18)+J(19)+J(20)
      N5 = J(21)+J(22)+J(23)+J(24)+J(25)
      N6 = J(26)+J(27)+J(28)+J(29)+J(30)
      N7 = K(1)+K(2)+K(3)+K(4)+K(5)
      N8 = K(6)+K(7)+K(8)+K(9)+K(10)
      N9 = K(11)+K(12)+K(13)+K(14)+K(15)
      N10 = K(16)+K(17)+K(18)+K(19)+K(20)
      N11 = K(21)+K(22)+K(23)+K(24)+K(25)
      N12 = K(26)+K(27)+K(28)+K(29)+K(30)
      N13 = N1+N7
      N14 = N2+N8
      N15 = N3+N9
      N16 = N4+N10
      N17 = N5+N11
      N18 = N6+N12
      N19 = N1+N2+N3+N4+N5+N6
      N20 = N7+N8+N9+N10+N11+N12
      N21 = N13+N14+N15
      N22 = N16+N17+N18
      N23 = N21+N22
      WRITE(6,23)I(1),N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12,N13,N14,N15
     G,N16,N17,N18,N19,N20,N21,N22,N23
      GO TO 333
  600 STOP
      END
```

APPENDIX D:QUESTION SHEET FOR PIAGETIAN TASKS

Determination of Levels of Intellectual Development

TASK I: The Conservation of Mass (2 points)

1. Will the sausage weigh more than the ball, or are they the same, or does the ball weigh more than the sausage? Why?
2. Is one ball heavier than the other or not? Why?

TASK II: The Conservation of Volume (3 points)

1. What will happen if you place the ball of plasticine into the jar of water?
2. Why will the water go up? (down?)
3. Do you think your model will take up more room than the the ball in the water, or less, or the same? Why?
4. Will one ball take up more or the same or less than the other? Why?

TASK III: The Separation of Variables (4 points)

1. What effects the time it takes for the ball to swing back and forth? Why?

TASK IV: Equilibrium in the Balance (4 points)

1. Where would you place this weight on this balance beam to balance the other weight? Why?

APPENDIX E: SAMPLE PRETEST

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Chapter Pretest

Answer all questions on the answer sheet provided

When completed, return all materials to your teacher for scoring.

1. Consider the chemical reactions shown below. Which one of these reactions is the most endothermic?

   (A) $SO_2(g) \rightarrow SO_2(aq)$ $\Delta H = -6,3$ kJ

   (B) $NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$ $\Delta H = +26,5$ kJ

   (C) $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ $\Delta H = +4,96$ kJ

   (D) $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$ $\Delta H = -41,7$ kJ

   (E) $AgNO_3(s) \rightarrow Ag^+(aq) + NO_3^-(aq)$ $\Delta H = +22,8$ kJ

2. When 9,81 g of sulfuric acid (H_2SO_4) is added to 100 ml of water, the temperature of the water rises 1,78 °C. On the basis of this information, the heat of solution for sulfuric acid(ΔH) is which of the following?

   (A) -7,5 kJ/mole
   (B) +7,5 kJ/mole
   (C) -748 kJ/mole
   (D) +74,8 kJ
   (E) -7476 kJ/mole

3. Consider the following reactions:

   $1/2\ N_2(g) + 1/2\ O_2(g) \rightarrow NO(g)$ $\Delta H = +90,7$ kJ

   $NO_2(g) \rightarrow NO(g) + 1/2\ O_2(g)$ $\Delta H = +56,7$ kJ/mole

   What is the heat of formation, ΔH, for NO_2 gas from the elements N_2 and O_2 ?

   (A) -120 kJ/mole
   (B) -34 kJ/mole
   (C) +34 kJ/mole
   (D) +120,5 kJ/mole
   (E) +147,4 kJ/mole

4. The motion of molecules is very important in determining the structure. Internal vibrations play an important part in spectral analysis. The number of modes of movement found in NH_3,  , is:

(A) 2 (B) 3 (C) 6 (D) 5 (E) 7

For questions 5 and 6

I. $K(s) + 1/2\ Cl_2(l) \longrightarrow KCl(s)$ $\Delta H = -420$ kJ

II. $K(s) + 1/2\ Cl_2(g) \longrightarrow KCl(s)$ $\Delta H = -440{,}2$ kJ

5. Which one of the following statements regarding reaction I is FALSE?

(A) The heat content of the product KCl(s) is less than that of the reactants.

(B) If the reaction is carried out in an insulated container, the temperature in the container would rise.

(C) The reaction is exothermic.

(D) For each mole of KCl(s) formed, 420 kJ of heat is released.

(E) The E_p of the reactants is less than that of the products.

6. The formation of 24,9 g of KCl(s) in reaction II is accompanied by the release of:

(A) 20,2 kJ

(B) 146,6 kJ

(C) 420 kJ

(D) 440,2 kJ

(E) 220 kJ

Answer Key for Chapter Test: Form A

Question	Letter
1	B
2	A
3	C
4	C
5	E
6	B

APPENDIX F: SAMPLE POSTTEST

Chemistry: Unit Eleven

Energy Effects in Chemical Reactions

Chapter Posttest

Answer all questions on the answer sheet provided.

Upon completion, see your teacher for scoring.

For questions 1 and 2

(I) $K(s) + 1/2\ Cl_2(l) \longrightarrow KCl(s)$ $\Delta H = -420$ kJ

(II) $K(s) + 1/2\ Cl_2(g) \longrightarrow KCl(s)$ $\Delta H = -440,2$ kJ

1. Which one of the following statements regarding reaction I is FALSE?

   (A) The heat content of the reactants is greater than the product.

   (B) If the reaction is carried out in an insulated container, the temperature of the container would rise.

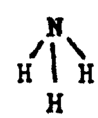
   (C) The reaction is exothermic.

   (D) For each mole of KCl formed in the reaction, 420 kJ of energy is released.

   (E) The potential energy of the reactants is less than that of the products.

2. The formation of 24,9 g of KCl in reaction II is accompanied by the release of

   (A) 20,2 kJ (B) 146,6 kJ (C) 420 kJ (D) 440,2 kJ (E) 220 kJ

3. The motion of molecules is a very important factor indetermining structure. Internal vibrations play an important part in spectral analysis. The number of modes of vibration in NH_3, , is:

   (A) 2 (B) 3 (C) 6 (D) 5 (E) 7

4: Consider the following reactions:

$$1/2\ N_2(g) + 1/2\ O_2(g) \longrightarrow NO(g) \qquad \Delta H = +90{,}7\ kJ$$

$$NO_2(g) \longrightarrow NO(g) + 1/2\ O_2(g) \qquad \Delta H = +56{,}7\ kJ$$

What is the heat of formation, ΔH, for NO_2 gas from the elements N_2 and $O_2(g)$.

(A) -120,5 kJ/mol
(B) -34 kJ/mol
(C) +34 kJ/mol
(D) +120 kJ/mol
(E) +147,4 kJ/mol

5. When a 9,81 g sample of H_2SO_4 (sulfuric acid) is added to 100 ml of water, the temperature of the water rises 1,78°C. On the basis of this information, the heat of solution for H_2SO_4 (ΔH) is which one of the following?

(A) -7,5 kJ/mol
(B) +7,5 kJ/mol
(C) -748 kJ/mol
(D) +74,8 kJ/mol
(E) -7476 kJ/mol

6. Consider the following chemical reactions. Which of these reactions is the most endothermic?

(A) $SO_2(g) \longrightarrow SO_2(aq) \qquad \Delta H = -6{,}3\ kJ$

(B) $NH_4NO_3(s) \longrightarrow NH_4^+(aq) + NO_3^-(aq) \qquad \Delta H = +26{,}5\ kJ$

(C) $AgNO_3(s) \longrightarrow Ag^+(aq) + NO_3^-(aq) \qquad \Delta H = +22{,}8\ kJ$

(D) $NaCl(s) \longrightarrow Na^+(aq) + Cl^-(aq) \qquad \Delta H = +4{,}96\ kJ$

(E) $NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq) \qquad \Delta H = -41{,}7\ kJ$

APPENDIX G: ITEM ANALYSIS OF CHAPTER TEST