CHAPTER - II

A REVIEW OF LITERATURE

For this study the literature was reviewed and reported under eight broad headings.

A) Laboratory Instruction

B) Processes of Science

C) Methods of Laboratory instruction

D) Types of Laboratory Skills

E) Recent Advances in Laboratory instruction

F) Factors affecting Laboratory instruction

G) Evaluation of Laboratory instruction and

H) Case studies of various countries.

A. LABORATORY INSTRUCTION

Let us the take issue relating to Laboratory instruction.

Roger, Ryan - Schroeder (1974) in their study "Inquiry and the development of positive attitudes" concluded that students who interacted with concrete materials to answer questions developed significantly more positive attitudes. This study also revealed that there is no significant loss of attitudes when text-book reading is mixed with materials-oriented Laboratory.

In a study "An analysis of several instruments measuring "Nature of Science" objectives" Doran, Gurerin

& Cavalieri (1974) in their study described the process of Science as composed of following components :

A. Observation which are selected, influenced by instrumentation and past experience, described and recorded accurately, and sometimes unexpected.

B. Measurement which has inherent error, and is a method of quantitative expression.

C. Classification which is an invention of man, used for the organization of data and is based on observed relation between variables and hence has inherent weakness.

Experiement which is used to test hypotheses and theories and to expose new areas to emperical exploration and used to the identification, manipulation, and control of variables.

Communication which is a method of recording scientific information and adding it to the cumulative "knowledge" and is an academic obligation. Which makes scientific information available for independent confirmation and verification.

f) Prediction which is achieved by the utilization of inductive logic, deductive logic and multiplicity of techniques and procedures.

g) Formulation of hypotheses, theories, laws and models.

In another study Hofstein, Zvi and Samuel (1976) established that 12th grade children had less positive attitude towards laboratory work than their tenth & eleventh grade counterparts. The sex and the science stream variable did not affect the laboratory work. The factorial analysis revealed that interest and attitudes towards laboratory work in high school chemistry instruction is not unidimensional as it has been assumed to be for science interest and attitudes towards science and school lear-ning.

Doran(1978) in another study concluded that recent advances in measuring science processes include study of actual student behaviour or pictorial representation. Apart from paper pencil test, actual performance of the process skills are tested. Investigators can begin to replicate and cross validate the research accomplished so far.

In another study Melson(1979) asserted that :-

(1) The evaluative and potency factors of attitude towards science class did improve significantly as did the evaluative factor of attitude towards science laboratory.

(2) The activity factor of attitude towards, science class as well as the potency and activity factors of attitude towards science laboratory appeared to improve significantly, but the lack of predictive-ability on initial to final attitudes and the lack of initial attitude similarly casts some doubt as to the strength of this conclusion.

(3) All the factors of attitude towards science teachers, school and topic of the material appear not to have been significantly affected.

In yet another study welch, Kloffer, Aikenhead & Robinson (1981) argued that every student outcome with respect to inquiry in science education should have psychological consistency, be compatible with personal goals and have ecological consistency.

In an important study Ganiel & Hofstein (1982) concluded that practical Examinations have several drawbacks since the assessment is based on clearly defined criteria. Such examinations are not very useful, because their outcome will be greatly influenced by personal preferences and the biases of the practical examiner.

The two authors found that by using the Assessment scheme the assessment of laboratory was greatly improved both in precision and objectivity.

(Details in Evaluation of Laboratory)

They disaggregated marks into five categories as under :

a) Construction of the experimental set up and other manipulative skills (15%)

b) Observation and measurement (25%)

c) Ordering and organization of the work (10%)

d) Organization and Processing of the data (25%)

e) Drawing conclusions and critical discussion (25%)

In another study Shymansky & Mathews (1974) concluded that observational data on student behaviour in the class room revealed significant differences between two groups of students in several behaviour categories. Student under the non-directive pattern of teaching showed a increasing tendency towards self-actualization in the science class room while the dependent of the teacher structured student appeared to increase.

* TAB test data revealed further a significant difference in the student investigative skills in favour of the student structured students with most dramatic difference appearing in the performance of low ranking student.

A study by Tobin & Capie (1982) concluded on the basis of logical analysis and empirical studies that student engagement rates are found to be closely related to his achievement in science.

In another study by Abraham (1982) three possible formats were investigated (a) verification laboratories (b) Guided Enquiry laboratories, (c) open/guided inquiry laboratories using several techniques of data analysis.* LPVI as an example of a Q sort instrument which has proven useful in examining the formats of laboratory types used by :

- Suggesting modifications
- In comparing trestments of a educational experiment it can be useful especially when used to rationalise difference identified by other measurements.

~~*TAB stands for JRST [illegible]~~

*LPVI stands for Laboratory Bogram variables inventory,

~~JRST (155-165) 1982~~

- Valuable in monitoring the development and implementation of new instructional materials.

- The effect of teacher education projects, designed to train teachers to use particular instructional strategies and techniques.

- Operationally define constructs.

In future Q sort can also be used in conjuction with other descriptive measures such as interaction analysis to see how Q sort can augment these methods.

In a study Kozma (1982) found that students who tended to be more conforming were more satisfied with the structured approach. The more motivated students seemed on the other hand satisfied by the challenge presented to them in the less structured approach. These preferences did not, however, effect either of the performance measure with all groups learning more from the more structured approach.

The complex interaction among treatment, ability and anxiety seem to suggest that both non-anxious learners who lack ability and able learners who are highly anxious prefer structure.

The interpretation of this pattern is that without external directions the less able, the less anxious student remain lost and apathetic, while able anxious learner is lost in frantic shifts of attention and effort. This pattern does not affect learning, however with all students learning better with high structure treatment.

In a study Rouse(1981) compiled a list of basic learning objectives for a high school chemistry course.

The suggested basic learning objectives are as follows.

The student will be able to :

1. Demonstrate an understanding of basic measurement techniques.
2. Demonstrate the ability to record laboratory measurements utilizing metric units of measure.
3. Convert metric units to both English and other metric units.
4. Properly use basic laboratory equipment.
5. Explain and/or demonstrate the proper use of laboratory safety equipment.
6. Explain the meaning of the law of conservation of matter and energy.
7. Demonstrate problem solving technique necessary to solve problems relating to topics such as density, formula mass, percent composition, stoichiometry, gas laws, molarity, emperical formula and molecular formula.
8. Use significant figures and scientific notation when recording measurements and performing calculations .
9. List the correct symbol and name for common elements (including IA-VIIIA) and commonly used transition elements).
10. Utilize the periodic table to locate elements and predict their properties, atomic number, oxidation number, and

atomic mass.

11. Write correctly the chemical formulas of commonly encountered compounds and state their most commonly used names.

12. Write and balance simple chemical equations.

13. Define terms such as exothermic, endothermic, mole, atomic number, isotope, electron, proton, neutron period, family, ionic compound, ion, covalent bond, kinetic energy, melting point, boiling point, equilibrium and calorie.

14. List and describe the properties of each of the states of matter.

15. Define acid and base according to Bronsted and Lowry theory.

16. Use a pH scale to distinguish between an acid and a base.

17. State the general chemical composition of household chemicals such as detergents, poisons and common medicines.

18. Identify and give a common example of each of the basic types of organic compounds including esters, alcohols, ethers, aldehydes, acids, amines and hydro-carbons.

19. List and explain the assets and liabilities of the different energy source options.

20. Discuss the good and bad effects of the use of chemicals (i.e. medicines, cosmetics, food additives, pesticides.).

Leenard (1983) recomended that biology laboratory investigation should employ extensive use of science processes, concept development via systematic questioning and increased demands upon student use of discretionary resources. It is suggested that if it is important for students to develop scientific inquiry skills, provisions must be made for students to earnestly engage in these activities as opposed to only following directions and answering questions. This study contradicted past studies at the secondary level indicating little or no difference in student performance between the*BSCS and other biology laboratory approaches.

Kolodny (1983) claimed that:

(a) Quizzes helped students understand what they were trying to do in the laboratory by forcing them to read the manual and reinforcing the ideas present in the manual.

(b) Quizzes provide practice calculations and helped relate them to the laboratory work.

(c) Quizzes were fun (in part because they were wellesly specific.)

* BSCS stands for Biological Sciences Curriculum study.

(d) Quizzes were comprehensible and easy to use.

In his comprehensive study Lash (1977) argued that in order to assess the importance of the factors involved in the analysis of the learning environment of a science laboratory, there is a similarity between1976 and 1820 in forces pressing for change in higher education both in instruction and organizational structure (2) The concept of learning environments and the development of environmental psychology have been both increasing in importance. (3) A paradigm is needed in order to accumulate and minimize random results in educational research concerned with instruction. (4) Laboratory instruction has maintained its historical purpose and is still determined to be essential.

(5) Instruction in the under-graduate Laboratory is changing towards a more individualized and personalized style.

(6) The discipline of science currently exhibits shifts in its traditional paradigm.

Pursuing the same issues Lee (1977) asserted that:

a) A substantial percentage of college freshmen need to be trained at an abstract level of thought before they can handle the rigour of the molecular abstraction and chemical sophistication of modern college level science courses.

b) College students can be trained to function at an abstract level of thought through instructor directed inquiry centred learning and laboratory manipulation of surrogate concrete concepts leading upto abstract conceptualizations.

c) Students need to understand how ideas and theories are derived from concrete observation and experiments.

d) The laboratory is an essential part of any science course.

e) There needs to be a conceptual coordination between the lectures and laboratory sections of any science course.

f) Concepts should first be introduced at the concrete level in the laboratory and afterwards developed at abstract level in the lecture.

g) The scientific method in conceptual model building should be illustrated in the science classroom with a balance between the use of inductive reasoning in developing ideas and theories and deductive reasoning in applying ideas & theories.

Taylor (1978) argues that ranking form and laboratory function for both can be used to assess the perceptions of students laboratory teachers, and faculty members about the functions of laboratory work in introductory course in college biology. The results of this study also suggested several ways in which the instruments might be revised to make them more useful.

Mark (1979) in his study concludes that large differences between students in the proto-type laboratory compared with students in the standard laboratory of the same course. Students in the proto-type laboratory could perform basic skills more flexibly and more reliably. They can also give verbal descriptions clearly superior. They are more successful in solving problems requiring flexible understanding of their experiments and are better able to summarize the essential ideas of their experiments.

Students in the proto-type laboratory state that they learned more useful skills and they understood better the experiments done by them. They also claimed that they enjoyed the laboratory more and considered the time they spent in the laboratory to have been more worthwhile. Finally the attitudes of teaching Assistants about the laboratory are much more positive in the proto-type laboratory than in the standard laboratory.

According to Roger (1980) properly designed indepandant study materials can allow home study students to learn laboratory based high school chemistry independent of the school settings as effectively as self paced classroom students with respect to their knowledge of chemistry and laboratory skill development while exhibiting relatively positive attitudes towards chemistry. The sequence and integration of independent study instructional materials in chemistry contribute substantially to home study students achievement in three domains of learning.

In a recent study Isom (1984) concluded that pre-laboratory preparation period increased the academic performance of students taking introductory chemistry laboratory course at Aurburn University and serves as a viable alternative to the traditional pre-laboratory lecture format.

David (1984) has taken the view that, within the limits of his study and bounded by the sample studied, laboratory does not contribute significantly to student achievement in the cognitive domain of the lecture section.

Dodge (1983) in his study concluded that interaction in the laboratory was not an accident but a complex social encounter. In the study the inquiry process moved from an examination of teacher role management patterns and finally to teacher-student interaction. The study suggests that the teacher role is a function of the transetion between myraid of extrensic and intrinsic factors and that the individual instructors perception of role not only influences the leadership management patterns employd in the laboratory but ultimately the amount and type of teacher - student interaction. The theoretical model of teacher-student interaction developed in this study portrays the dynamic encounter of teacher and student(s) within the classroom settings. The study has implications for both improving instruction and for teacher training. The interactive model has implications for educational researchers interested in class room instruction.

Edward (1982) suggested that student perception of the class room was more goal directed, more satysfying but less competitive and democratic than their laboratory perceptions. Inquiry oriented activities were perceived by students, to be more cohesive but less satisfying, less organized, and less difficult than traditional activities. Gender and differences in grade level caused little variation in student perceptions of their learning environment.

Perceptions of learning environments by classes of average and high ability students were similar Classes with low ability students perceived their learning environments to be more cohesive slower in pace, more goal directed, and more difficult than students in classes of average ability. Students in classes of low ability perceived the learning environment of the laboratory to be more difficult and more diverse than that of the class room.

Howard (1983) found that post-laboratory tasks were found to be more effective in influencing microbiology achievement than were transfering tests. There was no evidence of influence of college orientation on microbiology laboratory achievement. Students having high aptitude are better in microbiology laboratory than lower aptitude students and students at higher levels of cognitive development achieved better than students at lower cognitive levels.

Pilecik (1983) concluded that the historical treatment did help to improve student scores on the cognitive measures and pupul interest in biology.

(B) Processes of Science

Various researchers have made the following contributions regarding processes of science:

The study by Tomera (1974) established that lateral positive transfer of the skills of observation and comparison from one set of objects to another set of objects is possible. The study has raised many other questions relating to the transfer ability of various laboratory skills.

Tobin & Capie (1982) in their study on integrated science processes have concluded that"Test of Integrated Science Processes" (TISP) is reliable and valid. They have also concluded that the test has direct applicability to class room based research and evaluation of instruction and learning. The test apart from having sound psychometeric qualities is distinctive because it includes a set of interlated cumulative objectives which reflect autonomous problem solving.

Berger (1982) concluded that time of estimation appears to be a measure with sufficient variation and individual student stability appears to be appropriate as criterion to measure skill in estimating. It can be argued that time to estimation is not good criterion of the process of estimation. We believe that given the high accuracy of estimates after the first few estimates at each level, time of estimation, coupled with equal accuracy is a fair criterion.

Padilla, Okey & Shaw (1983) in their study concluded that science process skill ability is strongly associated with logical thinking and is therefore, a candidate as a factor that has a direct influence on it. The study has raised many new questions about the process skill abilities will have an influence on logical thinking. It is also possible that logical thinking influences process skills. If alternations in either type of ability has an influence on the other.

Finley (1982) concluded that observation classification, hypotheses, and inferences that are made, the order in which they are made, and how well they are done are likely to depend upon the conceptual knowledge of the individual.

In another study Finley (1983) concluded that science is conceptually driven and is consistent with the logical empiricist view of science as hypothetical deductive rather than inductive. It further argued that science is most rational as a deductive process of confirmation. The core of this view is that scientists formulate tentative hypothesis based on their conceptual knowledge early in an investigation. The hypothesis determines what data will be collected and how research will be conducted. It is thus the foundation for the ideal deductive argument (a modustolens argument) an an ideal explanation (a deductive nomological explanation). Conceptual knowledge is clearly essential in guiding all scientific enquiry. Some other implications were that conceptual knowledge drives the science processes and does not result from them. Second, science processes are context bound. Third, the relationship between the content and process must be better understood.

A study by Haukoos & Penick (1983) concluded that:

a) Class room climate does influence the learning of science processes, (b) sufficient time would appear to be needed to learn science processes (c) students may loose their knowledge of science processes if they are not continually emphasized through use during instruction.

Stevens (1975) in her study concluded that:

a) There is a total gain score for all sub-groups

b) There is a gain scores on the process skills of infering, measuring and experimenting for all sub-groups

c) There is a total gain score between higher ability level and lower ability level.

d) There are gain scores on process skills of observing, comparing infering, measuring, quantifying and experimenting in a comparison of groups of higher ability level and lower ability level.

Dawson (1975) in his study concluded that differences in critical thinking abilities or knowledge of the processes of science between guided decision making and conventional direction following were not significant. There was also no difference in the final grades of the lecture portion of the course. In addition, there was no difference in classroom behaviour or the number of kinds of questions the teachers asked.

Sallam Safia (1981) in his study concluded that inquiry instruction as presented in the study did indeed improve the attitude of pre-service elementary teachers towards science and should it be given keeping in view the level it pertains to science teaching. Also the areas of the acquisition of the integrated science process skills, formulating hypotheses, interpreting data and composite skills(overall integrated science process skill) were improved significantly.

Haukoos (1981) in his study concluded that science process scores for the discovery treatment were significantly higher than those for the non-discovery. Process scores for the non-discovery treatment went down, reflecting that students may lose their knowledge of science process if they are not continually emphasized through use in instruction. Discovery and Non-discovery class room climate treatments were equally effective in teaching course content since there was no significant difference between treatment.

Brooks (1982) concluded that no significant differences were found in levels of achievement between mastery and non-mastery average or above average students. Above-average mastery instructed subjects scored significantly higher than their non-mastery counter parts on an instrument measuring retention of low level process skills but average mastery instructed subjects did not show any siginficant differences in retention from non-average non-mastery subjects. Both average and above average mastery instructed subjects scored significantly higher than their non-mastery counterparts on an instrument measuring retention of higher level process skills. While mastery instruction may not be significantly better than non mastry instruction in affecting achievement gains when equal amounts of time are spent in both modes of instruction. The mastery instruction strategy can sometimes produce a more permanent mastery of sequentially organized materials (higher process skills) than an equivalent time non-mastery instructional strategy.

Ilyas (1983) in his study found that teaching of science process skills to inservice secondary school teachers enabled them to acquire science process skill competence.

select science process objectives and process activities significantly better than untrained teachers. However no significant relationships were found to exist between teachers Open-mindedness/attitudes and four dependant variables.

C) Different strategies of Laboratory Instructions

Now let us examine the literature regarding different strategies of laboratory instruction.

(i) Demonstration

In a study by Eniaujeju (1983) concluded that higher achievement in concept acquisition and problem solving skills under self paced instruction indicates that the technique can be profitably used to teach the areas of chemistry selected for the experiment. Success under self paced was most likely a consequence of greater degree of personal involvement leading to better and greater depth of understanding in the learning process working individually through the self paced materials required the students to rely on feed back and pay attention to every step of the work. The students progress was not limited by that of a weaker student. The over-all effect of the approach was therefore the acquisition of greater knowledge of chemical facts and the better ability to apply them in problem solving situations.

The teacher demonstration method on the other hand, appeared to have lowered student achievement through teacher-management and the more or less passive role of student during the presentation of lesson.

Beasley (1982) has indicated that only nine of the twenty four teachers in this study were observed using class demonstration methods. However the significant aspects of these classrooms were the increased levels of pupil-attention and task involvement during demonstration lesson segments. Expository methods were much more common, but in the eyes of the pupil teachers perform best when they ~~was~~ are conducting the classroom demonstration.

Al-Faleh (1981) in his study concluded that small group experimentation group exhibited significantly greater chemistry achievement than the lecture-demonstration group, on both immediate and delayed tests. The results also indicated that the students in the small group experimentation group possessed more desirable attitudes towards science than those in the lecture-demonstration group. A non-significant correlation coefficient between the immediate chemistry achievement and immediate attitudes towards science suggested that no relationship existed between the two dependent variables for the lecture-demonstration group. The results obtained also indicated that there were no relationship between the immediate chemistry achievement and immediate attitudes towards science for students in the small group experimentation group.

Louwerse (1982) in his study concluded that given the same conditions, there is a place for both individual student laboratory experiments and/or teacher demonstrations of experiments in secondary school science instruction.

ii) <u>Experiments (Individual/group)</u>

Lowell & Lawerence (1975) in their study concluded that use of small group enhances successful task completion. It also might provide an advantage to students working first individually, then in groups compared to those who work only in groups.

To design and carry out an experiment is a complex cognitive undertaking. There are a variety of conceptual schemes that break this complexity into a set of discrete skills, the known being the AAAs* objective (1965). The difficulty with this is that it is specific to science, that is the relationship to problem solving skills in other domains is not explicit. Consequently training students in the mastery of this set of skills reduces inter subject integration and minimises opportunities for reinforcement of experimental problem solving in other disciplines.

In the present study the domain of experimental problem solving was organized in terms of a chronological account of what successful scientists do when designing an experiment. The labels used for the skills were of sufficient generality to be applicable in other subjects and in other types of problem solving such as correlational analysis, comparative thinking and decision making.

* AAAS stands for American Association for Advancement of Science.

1. Develop a focus for the investigation (in science this skill is typically labelled formulate an hypothesis).

2. Establish a frame work for the investigation (in science this skill is called design the data collection).

3. Record the data.

4. Judge the adequacy of the data.

5. Observe relationships in the data.

6. Draw conclusions.

7. Extrapolate the conclusions (in science this skill is usually called generalization).

Within this set the skills of developing a focus and establishing a frame work were selected for special attention in the design of instruction. These skills were selected because they are chronologically prior to subsequent procedures and because there is anecdotal evidence that they are even less likely to be taught than the other skills in the set of the two skills the most important is establishing a frame work. It is in the context of this skill controlling variables is addressed:

The skills were operationally defined by constrate the behaviour of mature problem solvers with the behaviour of mature problem solvers with the behavior of novices. The differences between novices and experts were decomposed into a series of levels of intellectual performance (a growth scheme) that could reasonably be expected of students in the target population - in this study grade sixth. This logical analysis was suplemented with observations of students and analysis of responses to open ended test items. In this conception of experimental problem solving, the lower levels of performance are not so much incorrect as inadequate. Immature problem solvers begin with operations that are part of higher level performance but unlike experts, novices come to premature closure.

Growth in experimental problem solving involves modification of cognitive behaviors up the hierarchies. The purpose of instruction is to accelrate and extend natural development. Without instruction it is assumed that students would progress very slowly and that many would plateau before the higher levels have been reached.

There is no assumption in this conception of experimental problem solving that the levels of performance constitute universal invariant hierarchies. It is assumed that most students will function at higher levels on problems using familiar apparatus and familiar science concepts.

Lynch (1978) in his study concludes that a strong conviction among teachers and educators is that practical work should serve as an important means of facilitating learning and understanding. However the results cast some doubts on whether the extensive use of practical work, as it is at present confers any special advantages in this respect. The results reflect poor implementation of the practical work. An important consideration is that in south African and indeed throughout the third world, cost effectiveness can not be ignored.

iii) Inquiry:

Rachelson (1977) in his study concludes that students are most often presented hypothesis and are not encouraged to generate their own. Educational outcomes are based too heavily upon the logical, observable and repeatable. Science Education is placing too much emphasis on equipping students with the technical skills to conduct experiments without providing enough experiences which lead to creative hypothesis formulation. In order to present wholistic view of scientific enquiry, hypothesis generation strategies derived from the practice of science must be included with equal emphasis into the planning of science education experiences for all students.

Tamir (1983) claimed that there is a strong evidence in favour of inquiry in science class rooms. He further suggested that a reform in teacher education programmes may be the key for more successful implementation of inquiry oriented science teaching in schools.

Kyle (1980) shown that ability of the teacher to ask questions and to stimulate and facilitate creative and critical thinking does not enable the student to perform scientific inqiiry. The ability to scientifically inquire is the personalized, internalized ability of an individual to synthesize the knowledge which has been obtained through the learning of basic process skills and competencies that enables a person to rationally inquire and solve problems by means of unrestrained indictive thinking.

The learning process must confront the student with problems not mere statements of fact, and there must be appropriate and meaningful intellectual transactions going on in class room or laboratory at whatever level of instruction is appropriate and meaningful for each individual student. It is only through such a learning process that any student will have the desire to, and feel the challange to scientifically inquire.

Students in more inquiry oriented science class rooms showed higher critical thinking skills, viewed science as more tentative, and held more favourable attitudes towards the science teacher and science class than did students in physical science class less inquiry oriented.

Sanford (1978) in his study concludes that teacher charac-terstics appeared to be more significant determiners of the extent of use of inquiry strategies than were academic aptitude levels of classes.

Botti (1980) in his study concluded that:

a) The subjects regardless of teacher laboratory verbal treatment, did not differ statistically in mean score performance on understanding science as measured by Welch's Science Process inventory or on scientific attitudes as measured by Allinsons adaptation of the Allen - attitudes Scale.

b) The congruent treatment subjects earned significantly higher mean scores in cognitive abilities, relative to the understanding and use of science processes as measured by the evaluation of individual science projects than did the incongrauant treatment subjects.

El-Nemr (1980) in his study concluded that a definite superiority in favour of the teaching of biology as inquiry over the traditional approach in helping students develop most of the instructional outcomes. Students taught by the inquiry mode of instruction improved their science process skills, scientific attitude, critical thinking, achievement and laboratory skills more than students taught biology by traditional approach. The development of process skill by inquiry teaching did not reduce mastery of content.

Omar (1981) in his study concluded that the interactive practice oriented inquiry instruction provided the experimental group prepared teachers who stated a significantly greater preference for and than did the control group teachers. The inquiry teaching performance of the trained teachers can be predicted from their preference scores. Teachers dogmatism (open or close mindedness) as measured, was not significantly related to either the teacher preference or use of inquiry teaching behaviour.

Sarnit (1982) in his study concluded that educational back-ground was the only factor that affected the knowledge of inquiry teaching of science instructors. Science instructors who had a master's degree understood the knowledge of inquiry teaching better than science instructors who had a bachelors degree. But the educational background did not effect the science instructors use of inquiry behaviours. It was also found that there was no relationship between the knowledge of inquiry teaching and the use of inquiry behaviours of science instructors.

Johnstone (1980) in his study concluded that students who score high in achievement tests and on operations tests tend to earn higher grades in both inquiry and non-inquiry classes than children with low achievement scores and operational test scores. It also suggests that success in an inquiry science class is based on combination of high achievement scores and higher operational level.

X Awodi (1984) in his study concludes that:

a) Teaching science as inquiry siginficantly enhances Nigerian student achievement in science (b) The inquiry method is more effective method of teaching science than the traditional lecture-method.

iv) Investigation & Problem Solving

Mayfield (1976) in his study concluded that not all of the students increased their participation. Isolates and lower status group members in general were left out of the group acti ity. This is one aspect which may very well be as important as the development of problem solving skills and it is difficult to see how social development will occur if some members submissvely follow. The size of the group, the nature of the task and the ways of selecting participants each seem potentially valuable aspects for further study.

In a group ~~of~~ the choice between t o different speculative explanations is likely also to be a choice between adherents to the two notions even as in the adult world of science. The achievement of rationality in problem solving group depends upon the development of interpersonal competence, defined as the individual level of awareness as to what is happening in the group and what is he capable of doing about it.

When choosing to use small activities, teachers clearly need to make themselves and their students aware of the potentialities and pitfalls of working in groups. Teachers must be sensitive to the interpersual pressures inherent in small group activity. The teacher who wishes to maximize the success of small group activities must be willing to examine carefully the group and their activities as well as to choose carefully activities appropriate for small group instruction.

Shaw (1983) in his study concluded that students who had the process oriented science curriculum scored significantly higher on "objective Referenced Evaluation in Science" than those students who received a science programme emphasizing primarily content. It appears that laboratory approach to science alone is not sufficient to teach problem solving skills. The teacher sho ld develop a select curriculum that has a strong and a constant emphasis on the processes involved in problem solving. The results leave open the possibility that the use of these problem solving skills may transfer to other academic areas or to non-academic areas and make a person a better problem solver throughout life. A teacher should be confident of his/her students ability to use the basic processes before they are expected to master the integrated problem solving processes.

Raughbir (1979) in his study concludes that laboratory investigative approach has been shown to be a successful teaching methodology for high school science instruction. Students have shown sifnificantly higher gains for these cognitive factors; formulating hypothesis, Making Assumptions, designing and executing investigations, understanding variables, observing carefully, recording data, analyzing and interpreting results, and synthesising new knowledge and for attitude development, curiousity, openess, responsibility and satisfaction compared with the lecture - laboratory approach.

Students using the laboratory - investigative approach acquired a greater understanding of science, greater information retention, and better ability to think scientifically. A very important aspect of this methodology is that the gains the students make in the affective domain seem to have a positive effect on their achievement.

Peterson (1978) in his study concluded the following findings about the nature of scientific inquiry as performed by high school students and about its effective instruction are:

a) The value of focussed and specific training in scientific inquiry as opposed to more general curriculum is suggested.

b) The value of concrete experience for some aspects of scientific inquiry instructions was demonstrated, even for the older and science successful students of this study. These findings are contradictory to what the "meaningful verbal learning" theories of Ausubel might predict.

c) The findings support a model of scientific inquiry performance in which the various processes (e.g. observing, questioning, and designing experiments) are not equivalent processes i.e. they did not respond equivalently to the same training test performance, situation or instruction.

d) No gender differences were detected in the training progress.

e) The training programmes were effective in improving performance in a variety of inquiry skills.

John & Eugene (1981) in their study concluded that the problem solving approach employed in the study seems to be an effective means for improving the achievement of earth science students. It will increase test performance at the knowledge, comprehension, application and analysis levels. In particular this strategy appears to have greatest effect on the application of subject matter. Problem solving laboratory activities and teacher initiated questions at the analysis and application levels appear to be practical strategies to implement an earth science programme.

William, Gordon and Lowery (1981) in their study concluded that the tenth grade biology students, if given the training and the opportunity to exercising discreation are capable of using discreation to greater extent and with greater rewards than is presently being allowed. Students in the study were found to be able to learn on their own discreation for period 10-15 minutes at the begining of the school year and for at least three class periods so later in the school year. High school biology students appear to be academically flexible, when teacher expectations were increased students adjusted to these expectations. Students also adjusted successfully to seeking teacher help less frequently and only at specific times during laboratory investigations.

Ron (1984) in his study concluded that learning to make scientific discoveries (i.e. to solve problems) requires construction of qualitative relationship among piece of a system. Machine learning system such as BACON-5 support this assertion and show the importance of "expectation structures" (e.g. symmetery) in reducing the time required for discovery of scientific laws.

Science Education Research into how human learn science might be furthered by "Artificial" learning research such as BACON programmes at carregie-Hellon University. The internal programmes of such learning system can be modified and controlled to a far greater degree than seems possible with human intellegent systems. While it is recognised that human intellegent system are not pure cognitive systems but are composed for emotional and basic regulatory systems as well. It is not unreasonable to look at BACON like machine system to see whether they can provide insights that might be valuable in our search to more about how scientific problem solving is learned.

Tolm & Florence (1983) in their study has concluded that the problem solving effect can be explained by four principles derived from cognitive psychology. First the programme provided practise in component operation such that processing could become more rapid and efficient. The promotion of automaticity in operations reduced processing demands so that new operations could be accommodated into more complex executive schemata. Second, deficiencies of cognitive strategies were made visible providing students with an incentive to modify their mental operations. Third new operations were invented by students or modeled by teachers to redress the deficiencies discovered. New operations were presented as additions to existing cognitive behaviours rather than as replacements. The transition from one level to another occured as a smooth and natural progression. Fourth the programme attended to the metacognitive aspects of growth in problem solving skills by making students concious of their own cognitive behaviour and by providing students with labels and spatial representations for cognitive acts.

Use of student groups (compared to individual work) resulted in greater student peer tutoring and greater perceived mutual concern in the class room. The group work produced the highest incidence appear tutoring and greatest increase in number of correct problems when compared to individual and combined individual group work settings. Groupings provided means of interaction and discussion, sharing of oppinion improved communication, and resulted in increased insight into scientific phenomena. Development of student leadership, cooperation, communication of sense of belonging and responsibality as a result of structured groups. Increase peer tutoring and peer pressure within groups that helped to motivate low achievers and decrease absentism and incomplete assignments. The use of small groups at the college level enhanced indepth understanding of the material studied and development of skills and attitudes such as critical thinking and curiousity. Enhancement of motivation, positive attitudes towards use of course materials, improvement of problem solving skills, and increased depth of understanding by using small groups methods with adults.

The value of groups for developing attitudnal a qualities, motivational, social interaction skills, indepth understanding, greater retention of information gained have been recognized by the developers of inquiry role approach programme and contributed to the rationale for the extensive use of the small groups in the programme.

Dorthoy and Robert (1983) in their study concluded that it would be profitable for teachers to use supplemental, less mathematical and more visual approaches with high mathematics anxious students who also are deficient in proportional reasoning ability or have low visual preference. Apparently the combined verbal-visual approach shown to be superior for concept learning by Hollidar that makes the use of two components of the memory structure (Gangne & Whites) is effective for certain groups of students in learning to solve chemistry problems. Certainly the factor-label method should not be used exclusively for these type of students, because a a high percentage of high school students are not formal operational and because these students proportional reasoning ability will develop over time, these students may elect to take another chemistry course at a later time if they are taught problem solving in such a way that they experience success. This would most likely increase the number of persons selected scientifically related courses.

Ikponmwosa (1983) in his study had sought to provide evidences in this investigation to suggest that science teachers can and should bring intractible social problems into science classroom. With little creativity modification and adjustment instructional activities in the science classroom can be brought to bear on otherwise difficult social problems without necessarily losing the sharp focus of the science curriculum nor its objectives.

Dorthoy & Robert (1981) concluded that the number of high school science courses that preservice x elementary teachers take a important in their preparation to teach science. The number of high school science courses students take and success on the laboratory practical are related. If students are successful on the laboratory practical, they should be able to plan and carry out experiments in the classroom. The teachers should posses all laboratory skills if they are to teach science with hands on and enquiry orientations.

Lunefta & Tamir (1981) asserted that it was appropriate in the pursuit of certain goals to provide explicit instructions for laboratory procedures. Detailed procedures may result in more efficient learning. It is naive to assume that all important inquiry and problem solving skills can be developed simultaneously in a period or two. Selected inquiry skills can be emphasized in specific laboratories for which those skills are particularly appropriate.

The analysis of project physics & PSSC* hand books indicate that concerned teachers need to identify special opportunities in laboratory activities to encourage students to (a) Develop and wrestle with alternate hypotheses and design ways to test them (b) Follow their own procedures and imrprove upon techniques based upon alalysis of this experience

* PSSC stands for Physical Science Study Curriculum.

(c) Examine assumptions underlying the investigation and elaborate limitations in measurement and sources of experimental error (d) Apply what they have learned to the solution of the problem (e) Develop new questions based upon their experience.

In short we must continually examine our goals for laboratory instruction and work to see that our students are developing skills and experiences and insights that are as consistant as possible with the important goals.

Tavares & Tereno (1976) in his study concluded that the course independent of the use of Advance organizers does not increase the performance of the students in those outcomes that are evaluated through the instruments used.

Tamminen (1976) in his study concluded that there were no significant differences between the treatment and control groups. The programmed supplement of the general chemistry problems did not significantly improve the problem solving skills of the subjects. The observed effects were probably due to inherent characterstics of the students, teachers and the instructional methods involved in the study. The result of the study seem to indicate that all students do not respond similarly to this kind of academic reinforcement. Therefore, it is recommended that programmed instructional materials in college chemistry be offered to nursing students on an optional basis.

Pitt (1977) in his study concluded that performance of high school students was below that of college students by a number of different measures. Younger subjects defined the problem incompletely, made more errors in data acquisition algorithms used hypothetic deductive reasoning less effectively and tended to interpret data by simple pattern extraction strategies. Increased use of hypothetic deductive reasoning was observed at all age experience levels when planning constraints were imposed.

Piagetian formal operational prerequisites of abilities to contruct the combinatoral of all possibilities and to isolate and manipulate one thing at a time, were treated as algorithms. Both algorithms involved processing of matrices the matrix construction required for the coloured and colourless chemicals task was easier for all groups than the matrix analysis required for qualitative analysis task.

The deviations from linearity of processing and the grouping of sub routines that were observed in the protocols obtained were used to derive a revised model of problem solving in the format of hierarchal network, which was composed of the same sub-processes and sub-routines as the initial line as linear model.

Shaw (1978) has concluded that the treatment groups scored significantly higher on the problem solving skill portion of the science and social studies instruments indicating that problem solving skills can be taught by the process oriented science curriculum and that these processes will transfer to social studies content. No significant differences, were found between the two groups on either instrument for the basic processes with one exception. The treatment group scored significantly higher than the control group for the processes of classifying on the social studies instrument but not on the science instrument. Evidence was found to support the heirarchy model of process skills, strongly suggesting that mastery of the basic skills is pre-requisite to proficiency in the problem solving skills.

Mele (1978) in his study concluded that the experimental group using Kaplan problem solving curriculum scored significantly higher than the control group on the post test on piagetian concrete formal operational thought abstract reasoning, objective-subjective differential reasoning and critical thinking.

The study also concluded that additional research appears to be needed (a) to determine what experiences other than problem solving might facilitate entry into formal operation stage of thought (b) to determine whether piagetian stages represent a valid model for describing the intellectual process of post adolescent students (c) to investigate the relationship between problem solving and specific formal operational characteristics (d) to determine whether positive relationship existed between the learning of biological concepts and the improvement of concrete formal operational thought, abstract reasoning, objective-subjective differential reasoning and critical thinking (e) to determine some of the needs and problems specific to post adolescence in the area of piagetian concrete - formal operational instruction.

Russel (1979) in his study concluded that an instructional programme using a problem solving approach will increase over all achievement at the application and knowledge levels. Such an approach should include written problem solving activities and teacher directed classroom questions that emphasize application of knowledge.

Nurrenbern (1980) in his study concluded that.-

a) The limiting regant problems presented in the interview proved to be very difficult for students at both levels of intellectual development.

b) Many students missed the questions preceding the problems. This result enhances the possibality that the difficulty of the problem resulted from insufficient chemical knowledge rather than lack of necessary cognitive skills.

c) Concrete and formal operational students performed differently in the areas of "reading/organizing" and "evaluation". Formal operational students appeared to make lists, restate the problem, cheek solutions and change approach more often than concrete operational students.

d) Concrete and formal operational students did not exhibit any significant differences in the use of reasoning productive non-reasoning, and recall techniques. Reasoning techniques were not used very often in the student solutions to the problems.

e) Concrete and formal operational students committed many errors that were related to knowledge of chemistry content materials. There were no significant differences between groups in the commission of these errors.

f) Concrete and formal operational students did not exhibit any significant differences in the strategies used to solve the stoichiometeric problems. Both groups exhibited the strategy of forcing the problem information into some previously memorized from or/ relationship despite any inappropriateness of the form or relationship. In the few instances when there was evidence of reasoning, the behaviour was exhibited by formal operational students.

g) Concrete and formal operational students exhibited little knowledge of the relationship between the real world and the material they studied in the classroom.

Akinmade (1982) in his study concluded that manipulative science and student centered science instruction should be encouraged in Junior high science classroom in order to stimulate the development of positive attitude. Further studies should examine the decline of attitudes towards science courses in Junior high Schools.

Raimes (1984) in his study has concluded that the most successful problem solvers differed from the moderately successful and the least successful problem solvers in their tendency to recognize problem similarity according to structure rather than context. Additionally the most successful as well as the least successful problem solvers improved in problem solving success subsequent to their consideration of problem similarity.

Lawsiripaiboon (1983) in his study concluded that the px problem solving strategy used in the study seems to be an effective means for improving the over-all achievement of physical science students particularly achievement at the application and analysis levels. Problem solving laboratory activities and teacher initiated questions at the application and analysis levels are practical strategies to implement a physical science programme.

Hermann & Hinksman (1978) in their study concluded that if immediate retention is desired, the deductive method may be superior, especially if the learning task is difficult. However, a longer term of retention is generally desired. For the criterion of delayed retention, the inductive method did not take longer than the 'deductive method and was equally effective. Should the inductive method simultaneously develop the learners technique of discovery, for students who discover the rules in the learning task, then the use of inductive method is advantageous. For high school chemistry there is no support for the proposition that student groupings, on the basis of I.Q., gender or trait anxiety should be different for inductive & deductive methods.

Douglass & Kahle (1978) in their study concluded that the ability to solve problems with ease parallels piaget's formal thinking and the degree of field independent learner that a student demonstrates. Many researchers maintain that high school students are concrete, or at best transitional thinkers and that they might find inductive or inquiry based materials difficult. It is possible that the frustration and failure attitude associated with an inquiry or inductive approach may do more motivational harm than good at this stage of logical maturity and that an alternative instructional strategy may be more appropriate. A recommendation of this study would be to individualize instruction in such a way that global field dependant students are matched with deductive materials and analytic field dependent students are matched with inductive materials. Individualizing for two broad groups of students is a reasonable task for the class room teacher, which may increase student success, hopefully resulting in more positive attitudes and self concepts.

Lawrenez & Munch (1984) in their study concluded that apparently working in laboratory teams grouped according to formal reasoning ability favourably affects student physical science content knowledge achievement regardless of formal reasoning ability level at least in comparison with working in students choice group laboratory teams. Grouping according to this criterion however does not appear to affect formal reasoning development, the perceived classroom environment or the consolidation of intra group relationships. Even though these other variables were not significantly affected, it seems that the gain in content knowledge is sufficient to warrant recommending that grouping of laboratory patterns according to their formal reasoning ability. Perhaps a small grouping criterion affect on these variables was counteracted by the similarity of the rest of course experiences and further research using more classes and instructors may reveal significant differences. All the results however favour the homogeneously grouped class. This class had the highest POST-PSI* scores, the largest gain in formal reasoning ability scores, and was perceived by the students as being the most cohesive, the least competitive and as having the least amount of friction. Another criteria could be forming laboratory groups according to prior science background or try different sized groups.

Vincent (1974) showed that statistically there was no difference between the two methods for the parameters(immediate acquisition, retention, ability level of the student "knowledge" and "above knowledge" levels of information) tested. An oppinion survey suggested the students taught by the discovery method tbsa thbecbntespgreupheir oppinions and ideas more clearly

*POST-PSI stands for Post-Physical Science Inventory.

Whitehead (1974) in his study concluded that students taught by the student centred teaching method were found to have achieved at a significantly higher level than those taught by either the CHEM* study or the teacher centered teaching methods.

Students taught by the student teaching methods realize a significantly greater increase in scientific interest than those students taught by the CHEM study or teacher centered teaching methods. No significant difference was found in the area of critical thinking abilities. No significant difference was found in relation to sex and achievement gain in chemist change in scientific interest or change in critical thinking abilities. No significant interactions between type of teaching method and sex of the student with regard to either of the three variables were found.

Townes (1976) in his study concluded that the vicarious laboratory methods, students over all performance on all three criterion instruments used for measuring achievement exceeded that of the conventional laboratory methods students. It was also evidenced in the present study that the upper reading ability level students over all performance was better than that of lower reading ability level students. While the data reported on sex revealed that the over-all performance of the females exceeded that of males.

*CHEM stand for Chemical Education Materials.

On the basis of the data reported the vicarious laboratory method group showed greater competency in the use of science processes than the conventional laboratory group. Also this study revealed that the males exceeded the females in the ability to use science processes. While the lower reading ability level students exceeded the upperreading ability level students in ability to employ science processes.

As a result of this study it was concluded that there is no one best method of laboratory instruction. The study also revealed that application skills can be effectively achieved without direct contact with laboratory equipment apparatus and materials.

The study by Abhyankar (1977) revealed that males sixth grade students had significantly better attitude towards science than their female counterparts. This difference was larger in the student - structured learning in science strategy than the difference in the teacher structured learning in science strategy. A significant interaction was found between student's sex and the teaching strategy. Analysis further revealed that male students in SSLC* class room had better attitudes than male students in TSLS** class room but female students in TSLS classroom had better attitudes than female students in SSLS classroom.

* SSLC stands for student structured learning in science.

**TSLS stands for teacher structured learning in science.

Chisquare analysis of students responses to self concepts in science part I revealed no significant differences in students preference for the solution to a problem solving situation between the students in the SSLS class room and students in the TSLS class room. Analysis of variance on the self concept in science - part II revealed that male students had higher self concepts than their female counterparts. A significant correlation was found between students attitudes towards science and their self concepts in science implying students who have better attitudes towards science also have higher self concepts and vice-versa.

Seal (1977) in his study concluded that:

a) Students taught by audio tutorial with lecture laboratory method demonstrated significant achievement when their post-test scores were compared with pre-test scores.
(b) The audio-tutorial method was equally effective on student achievement gain as the conventional method (c) There was no significant difference in post-test scores for the items determined to be from the upper levels of Bloom's Taxonomy when the two groups were compared. (d) There was no significant difference in retention when retention test scores for the two groups were compared.

Serlin (1977) in his study concluded that initial tests for equivalence indicated that the three groups (i.e. two experimental groups and one control group) were equally skilled at the criterion abilities, prior to the treatment. At the outset male subjects were better at problem solving than female subjects. The discovery laboratory method was effective at increasing students science skills. On the problem solving post test, males again scored higher than females. Neither treatment, nor sex was significant on any of the three measures. The effect of taking previous physics course was not signi-ficant on any of the three measures. It was concluded that the methods used were effective at improving student science process skills. Evidence was also presented which suggested that this goal has not been successfully attained within the context of traditional physics laboratory.

Mckee (1977) in this study concluded that siginficantly higher performance on the achievement test for morning classes problem solving interviews for SSLS classes. Significantly higher confidence levels forSSLS classes, significantly higher levels of self motivation in SSLS classes. Black students performed better in SSLS classes than in XXSK TSLS classes. While no significant differences were noted for white students in SSLS & TSLS classes. Furthermore a significant three way interaction between teacher behaviour, ethinicity and sex variables in problems solving ability analysis showed that black male students in SSLS classes scored higher than any other group while black male students in TSLS classes scored lower than any other group.

MCCALL (1978) in his study concluded that:-

a) Students learned significantly more cognitive content when taught by learning activity packages than when taught by learning activity packages than when taught by traditional class room lecture. This was found to be the case when comparing group mean scores for examinations in both phases of the study (b) students in responding to an attitude questionnaire exhibited a significantly higher level of satisfaction with learning activity package than with the more traditional class room lectures in both phases of the study.

Netivinyoo (1978) in his study concluded that:

a) The lecture - demonstration - Audio visual method was as effective as the lecture - behavioural objective method.

b) Different times spent in x instruction seem to have some effect on the cognitive achievement but not high enough to be significant at 5% level of confidence.

c) The combined teaching method of lecture demonstrate audio visual and lecture behaviour objectives was as effective as using each single method alone in teaching the units.

d) The demonstration method did not effect the cognitive achievement or the test scores on units.

e) Viewing the film did not effect the cognitive achievement of test scores.

Trummell (1979) in his study concluded that for developing the student ability to identify correct vocabulary, it appears that no weekly small group session is needed. However, if one is provided the weekly student initiated small group session appear to be superior to weekly instruction directed small group sessions.

To develop the student's ability to identify correct statements of principles, the choice of small group session is of important for those students with the pre-test mathematics scores in the lower two thirds of the class. For these students it appears that the use of weekly hand-outs to supplement the lectures and weekly laboratories is superior to the other instructional procedures. For students with pre-test mathematics scores in the lower one third of the class, it appears that the students ability to understand the meaning of physics principles is best achieved by supplementing the lectures and weekly laboratories with weekly student initiated small group session. For all remaining cognitive skills studied, the four methods of instruction appear to be equally effective.

Mcleod (1979) in his study concluded that laboratory instruction can be successfully used in the teaching of physical science - 100 with no loss in achievement. It was also concluded that the majority of students generally achieve higher group mean cumulative achievement scores when they are enrolled in a combined lecture - laboratory section of physical science - 100.

Ray (1979) in his study concluded that siginificantly higher performance on the critical thinking and abstract reasoning test for the class taught with higher level questions. It also concluded that both students with high and low grade point averages did better in the class room taught with higher level questions.

Bodine (1979) in his study concluded that the case study guided design approach as used in the bio-chemistry laboratory directed towards nursing students produces a very favourable attitude to the laboratory among these students. The students in the case study guided design laboratory section performed as well (using the average change on the pre & post test forms of the watson-Glaser critical thinking approach) though not significantly better, on the critical thinking test than did the control group. The student in the case study guided design laboratory sections performed as well though not significantly better on the examinations given on lecture.

Boghai(1979) in his study concluded that in terms of student achievement the "laboratory first" method was found to be superior to the "discussion first" method. Students with different levels of aptitude and noticeable performance differences for each of the experimental groups. Low aptitude students made significantly better progress in the "laboratory first" method and it was somewhat superior for medium aptitude students.Both methods seemed to work equally well for high aptitude students-Teaching Assistan show no influence on the treatments, but there was an indication that teaching Assistants have differing levels of ability.

Zervos (1980) in his study concluded that self concept occupies a position at the apex of the hierarchy with situation specific self concept at the base. To be consistant with the skill development theory, an educational intervention must influence specific science experiences to effect changes in academic self concept in science. In addition to the quantitative findings indicating academic self concept and achievement gains, changes in observed class room behaviour presented further evidence of improved performance among the students. Substantial improvement appeared with respect to students self-discipline, cooperation, observation, skills, questioning ability, interest, initiative and participation during the instructional treatment.

Lungo (1980) in his study concluded that regular ability students learn more effectively via deductive exposition whereas remedial ability students learn more effectively via inductive guided discovery in terms of initial learning. However, this was reversed for transfer of learning. For transfer regular ability students achieved higher levels of transfer via deductive exposition. It was also apparent from the study that field independent, regular ability students performed at higher levels of initial learning transfer and retention irrespective of methodology.

Bock (1980) in his study concluded that, no significant differences due to either main or interaction effects were found when attitudes, or attitudnal changes were compared. There was a significant difference between the experimental and control groups at the top track level when the experimental group scored higher than the control group on the application of sub-test ACS-NSTA* high school chemistry achievement test. This aspect of the study is encouraging because similar results were obtained by Herron. (Chem study VS Traditional), significant correlations involving scores on shipley test of abstract reasoning and various performance variables measured in this study tend to support the work of others who have found a correlation between the developmental level of students and their performance in various science courses.

Levandowski (1981) in his study concluded that:-

a) From the first to fifth laboratory experiment and test, there was a progressive improvement in the students understanding of the epistemological frame work (Vee) in applying vee to the description of the study structure of knowledge involved in a laboratory experiment and in conducting new experiments in order to analyse physics phenomena and to establish knowledge claims.

b) The methodological domain of the Vee (Experiment) was more easily understood and described than the conceptual one.

c) Students main difficulties in the conceptual domain come from their (i) lack of mastery of the theortical background of the experiment (ii) difficulties in expressing relationships among concepts (iii) lack of knowledge about the nature structure, and functions of a theory and its component parts. These difficulties also represented obstacles in the description of the constant interplay between the conceptual and methodological domains.

ACS*_NSTA stands for American chemical society National Science teachers Association

d) Students in the methodological domain came from their lack of skills in the graphic representation and analysis of data.

e) The students receptivity to the use of the Vee was good (about 75% of the possible maximum by using the Sukert Scale).

f) Among the three experimental groups using the three different formative evaluation strategies there were no significant differences in terms of students performances, receptivity to the vee, and receptivity to the strategies.

One important aspect of this study was the deep and clear communication, between the author (teacher) and the students which was made possible by the use of the "vee language" in the analysis of the structure of knowledge involved in laboratory experiments.

The evidence that the vee has an excellent structure, a strong communication power, andit is likely to improve ability/ies in scientific inquiry are the most important findings of this research study.

Daume (1981) in his study concluded that students in the ISCS and traditional science did not differ significantly on science content achievement, science process achievement, and attitude towards science when the variables of reading achievement, mathematics achievement and sex were held constant.

No significant differences were found between the males and females in the ISCS programe on the variables of science content achievement, science process achievement, and attitude towards science when reading and mathematics achievement were controlled. In the traditional programmes however males scored siginficantly higher than females on science content achievement, science process achievement, and attitude towards Science. When the variables of reading and mathematics achievement were controlled. Subjects in the ISCS program scored siginificantly higher in reading achievement when the variables of mathematics achievement and sex were controlled.

Schellenberg (1981) in his study concluded that students achieve equally well in learning the facts and principles of the subject content, understanding the nature of science and scientific attitude from both the contemporary topics and standard topics laboratory approaches. This conclusion implies that other criteria such as cost and student and faculty interst should be used to decide between the two approaches. Also it is implied that the limited effect of the laboratory period may not be sufficient to provide measurable differences in the criterion variables. This study was very concerned with the monitoring of the treatments and results indicated that treatment monitoring can be achieved by a simple external instrument.

Tofte (1982) in his study concluded that the learning centre approach was an important and clearly more effective strategy for producing atleast short term scholistic achievement in the study of Geology especially that of rocks and minerals and that improvement in self concept associated with the learning centre approach added support for its use with introductory Geology laboratory students at college levels.

Oloke (1982) in his study concluded that the indoor-outdoor laboratory method of teaching ecology was more effective than the traditional method of teaching ecology in producing cognitive gain and was at least as effective in promoting a positive ecological attitude. In light of the limitations of this study, any generalisation of these results to other populations should be done with caution.

Al-Ruwashad (1984) in his study concluded that:

a) the lecture laboratory approach was significantly more effective than the lecture only approach in enhancing students chemistry achievement.

b) The lecture-laboratory approach was significantly superior to lecture only approach in fostering students scientific attitudes (intellectual and emotional attitudes)

c) students at Riyadh Junior College completing chemistry 041 were not as well prepared as students with high school chemistry background regarding achievement in chemistry.

d) There were no significant differences in the lecture-laboratory student achievement and attitudes due to instructor effect.

e) There were significant difference in the lecture only students attitude towards science and total science attitude due to instructor effect.

f) In both groups there was significant relationship between changes in student chemistry achievement and scientific attitudes, attitudes towards science and total science attitudes.

Sendelbach (1981) in his study concluded that the overall results indicate the orientation of teacher being related to a segmental conceptual frame work. Several of the individual frames within this orientation were identified to include a "material frame", "procedural frame", "time frame", "results frame" and "learning frame". This approach was significantly different from the hollistic approach of the literal programme. The teachers dominant concern and focus of attention was associated with instructional aspects which addressed engaging the students in manipulations of materials, and the associated class room management requirements. The teachers orientation also included a student learning frame, but due to time constraints and sequential process of addressing other frame first, was often not developed.

The teachers ability to engage the student in manipulation of materials, doing type activities was very high because of the importance of the corresponding frames related to materials and procedures. Observations of student behaviour during the study resulted in the generation of the hypotheses that the influence of the teacher perspective respected the instructional task for the student to one involving only the manipulation of the materials. The nature of instruction appears to be related to the frames the teacher has and their level of importance with respect to class room management and student learning.

Gillespie (Jr.) (1979) concluded that audio tutorial group showed higher achievement than lecture laboratory treatment group in genetics. Similarly in cell test A.T.T.* showed higher achievement than the L.L.T.*student behaviour on the group embedded figures. Both groups showed significant improvement if exposed to A.T.T. (upper/lower). In dropout rate both groups had statistically have the same drop rate. In a second indepndent test, the group embedded figures test scores and secondary college aptitude test scores were found to exhibit no correlation and can be considered to be indepndent variables.

(D) <u>Types of Laboratory Skills</u>

Let us examine the litreature relating to laboratory skills.

Sund & Trowbridge (1967) have made an attempt to identify the type of skills which science students ought to "be able to do better" after having taken the courses in science in the junior high school or senior high school.

* A.T.T. stands for Audio Tutorial Treatment.

* L.L.T. stands for lecture laboratory treatment.

They have listed five categories of skills which includes the following, acquisitive, organizational, creative, manipulative, and communicative. No attempt has been made to rank these categories in order of importance, or even to imply that any one category may be more important than any other. Within each of these categories, however, an effort has been made to list specific skills in order of increasing difficulty. In general it was felt that those skills which required only the use of one's own unaided senses were simpler than those which require use of instruments, or higher orders of manual and mental dexeteriϕty. The categories and the specific skills within them with some elaboration, are, as follows:

A. Acquisitive Skills

1. Listening - being attentive, alert, questioning.
2. Observing - being accurate, alert, systematic.
3. Searching - locating sources, using several sources, being self reliant, acquiring library skills.
4. Inquiring - Asking, Interviewing, corresponding.
5. Investigating - reading background information, formulating problems.
6. Gathering data - tabulating, organizing, classifying recording.
7. Research - locating a problem, learning background, setting up experiments, analyzing data, drawing conclusions.

B. Organisational Skills

1. Recording - tabulating, charting, working systematically, working regularly, recording completely.

2. Comparing - noticing how things are alike, looking for similarities, noticing identical features.

3. Contrasting - noticing how things differ, looking for dissimilarities, noticing unlike features.

4. Classifying - putting things into groups and sub-groups, identifying categories, deciding between alternatives.

5. Organizing - putting items in order, establishing a system, filling, labeling, arranging.

6. Outlining - employing major headings and sub-headings using sequential logical organization.

7. Reviewing - picking out important items, memorizing, associating.

8. Evaluating - recognizing good and poor features, knowing how to imrprove grade.

9. Analyzing - seeing implications and relationships, picking out causes and effects, locating new problems.

(C) Creative Skills

1. Planning ahead - seeing possible results and probable modes of attack, setting up hypothesis.

2. Designing - a new problem a new approach, a new device or system.

3. Inventing - creating a method, device or technique.

4. Synthesizing - putting familiar things together in a new arrangement, hybridizing, drawing together.

(D) Manipulative Skills

1. Using an instrument - Knowing instruments parts, how it works, how to adjust it, its proper use for task, its limitations.

2. Caring for an instrument - Knowing how to store it, using proper settings, keeping it clean, handling it properly, knowing rate capacity, transporting instrument safely.

3. Demonstration - setting up apperatus, making it work, describing parts and functions illustrating scientific principles.

4. Experimentation - recognizing a problem, planning a procedure, collecting data, recording data analyzing data, drawing conclusions.

5. Repair - repairing and maintaining equipment instruments etc.

6. Construction - building needed items of simple equipment for demonstration and experimentation.

7. Caliberation - learning the basic information about caliberation, calibera ing a thermomoter, balance, timer or other instrument.

(E) Communicative Skills

1. Asking questions - learning to formulate good questions, to be selective in asking, to resort to own devices for

finding answers whenever possible.

2. Discussion - learning to contribute own ideas, listening to ideas of others, keeping on the topic, sharing available time equitably, arriving at conclusions.

3. Explanation - describing to some one clearly, clarifying major points, exhibiting patience, being willing to repeat.

4. Reporting - Orally reporting to a class or teacher in capsule form the significant material on a science topic.

5. Writing - writing a report of an experiment or demonstration not just filling in a blank but starting with a blank sheet of paper, describing the problem, the method of attack, the data collected, the methods of analysis, the conclusions drawn, and the implications of further work.

6. Criticism - Constructively criticizing or evaluating a piece of work, a scientific procedure or conclusion.

7. Graphing - putting in graphical form the results of a study or experiment, being able to interpret the graph to some one else.

8. Teaching - after becoming familiar with a topic or semi-expert in it, teaching the material to one's classmates in such a manner that it will not have to be taught by the teacher.

Mere identification of skills to be taught is of course only a first step in the realization of a science objective.

In order to bring about skill development and ultimate mastery of the desired skills, the x teacher must devise suitable teaching plans and student activities. It goes without saying that, in this type of learning at least "learning by doing" is an important maxim. Pupils must be given opportunities to carry out activities which give repeated practice in the skills to be taught to. The laboratory becomes an important facility at this point because most of the skills involve procedures which to a greater or lesser extent require materials and apparatus.

Observation

Barufaldi & Dietz (1975) in their study concluded that children perform more successfully (make more correct responses) on the visual tasks when they observe and compare either the solid objects or the photographs of the objects than do these children who observe and compare the drawings of the objects. The different types of visual stimuli do not effect the performance of children on visual observation and comparison tasks which focus upon the physical attributes of colour or size.

The grade level of the children affects their performance on visual observation and comparison tasks which focus upon the physical attributes of colour, size, form or form detail.

The older the children, the more successfully they perform these tasks. Differences in sex affect the performance of children on the visual observation and comparison tasks which focus upon the physical attribute of colour. Females perform these tasks more successfully than the males. The males should be provided with additional experience with colour observation and comparison tasks.

The difference in sex does not affect the performance of children on the visual observation and comparison tasks which focus upon the physical attributes of size, form, or form detail.

The teacher should consider, in the selection of methods and teaching materials.

The sex of the child, and grade level of the individual in relation to the effect of different types of visual stimuli on his performance of certain tasks. The choice of physical attributes of colour, size, form and form detail in any teaching materials should also be done with consideration for characteristics of and differences, between sexes and among grade levels.

Shymansky & Penick (1979) in their study concluded that while collecting observational data in systematic format may seem awkward, even impossible at first, once the behaviour categories are learned, detailed & reliable observations can be obtained easily. Trading observation with an instructor or coding several TAS* and using the data as topic at the next TAS meeting can provide rather productive results. Start thinking about what was observed. Was the observed teaching consistent with the goals established for the laboratory instruction. Does the quality of instruction or what the students are doing meet with your approval. If not, you now have a place to begin.

Norris (1984) in his study concluded that the observational competence consists of three proficiencies, proficiency in making observation well, proficiency in reporting them well and proficiency in assessing correctly the reports

* TAS stands for teaching assistants.

of observation. The hypothesis is that a good observer is one who knows the conditions and principoles and can use them properly. The newer view holds observation reports, like all statements of science to be intrinsically fallible. There is a long tradition in science education of attempting to develop observational competence in students. The guidance has extended to encouraging students to bbserve carefully, precisely and thoroughly and to report their observations accurately. Students should in addition should be made aware of the effects of emotional states, theortical understanding, preconceived notions and observational access among other things on the quality of observations, also more attention should be paid to the assessment of the reports of observation. Although observational competence is needed in many fields, and in many aspects of everyday living, science teaching is a very sensible place to promote it. There is a long tradition in science education which recognises the importance of competence in observing.

In addition without falling to the past trap of thinking of observing as infallible or clearly demarcated by language used. Science more than any other field relies at its very foundation upon sound observation.

Baker & Talley (1974) in their study concluded that the significant relation of visualisation skills with learning of problem solving skills in inorganic chemistry. This study and other noted recommend the consideration of the use of concrete models in the teaching of chemistry.

Lowery and Allen (1978) in their study concluded that the possible universality in the ways in which children solve problems involving size, shape, pattern, combinations of properties, fine differences, and varied orientations at the res&mbalance sorting level of cognitive development. The types of difficulties and success experienced by both sets of children were essentially the same. From an instructional view the establishment of a universality of behaviours at the resemblance sorting level and the ordering of difficulties within that level have major curriculum implications. Regardless of cultural diversity, it may be possible to identify an effective and perhaps efficient sequence of pictorial tasks for reading and mathematics work-books as well as for science materials.

Stevens (1974) in his study concluded that (a) observation is more than just seeing, looking or glancing (b) There are limitations on the abilities of teachers to be conversent with students observation (c) there are limits on the teacher's ability to evaluate student observations (d) There are limits on a teacher ability to provide autonomous observation or autonomous inquiry. (e) Observations do not have clear beginings or endings. (f) There are difficulties in determining the relationship which obtains between observation and various disposition the observer has concerning what is being observed.

Maguiree (1974) in his study concluded that an evaluation by twenty two science educators confirmed the general design of PSLOT* but rejected three of the dimensions. The other seven were well supported, PSLOT consists of ten dimensions assembled - - - -

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PSLOT* stands for Physical Science Laboratory Observation Taxonomy.

from clusters of overt student behaviours in the laboratory both verbal and non-verbal.

Willard(Jr) (1979) in his study concluded that a visual approach in presenting advanced organizers is better than any other method of presenting new materials. The results support the suggestion that teachers do not need to link prior learned concepts to new learning to facilitate that learning. It is possible, however that students need to contrive or construct to new learning to facilitate that learning. It is possible, however that students need to contrive or construct their own memory link to former learning to make an organizing structure work. It is further concluded that an operational definition of an an advanced organizer needs to be agreed, on, in order to provide continuity and direction for future researchers.

Classification

Lowell (1979) in his study concluded that many students in Junior high school and high school have difficulty solving problems requiring abstract reasoning ability. More specifically, a substantial number of these students experienced difficulty in organizing information in hierarchical arrays. Since hierarchical classification ability plays a crucial role in development of more complex thought process, this suggests that frequent experiences with hierarchial classification problems should become an important part of junior and high school curricula.

Levin & Libman (1980) in their study concluded that there is need for further search and for a greater differentiation between the cognitive process involved in free and guided classification. It further implies the need to place more emphasis in science and mathematics school curricula on free classification activities. Such activities enable teachers to begin their instruction from where the student is. It provides the teacher with information about the capabilities of his students and aids in developing a large range of learning experiences aiming to improve the ability to classify, to differentiate, generalize and Abstract.

Lowell (1980) in his study concluded that it was observed that hierarchial classification ability begins to be developed in children at around 11-12 years but does not become fully developed untill midadolescence (14-15 years) or beyond. The results strongly support Piaget's contention that hierarchial classification is not properly understood untill late concrete operations and in some cases the child may be at the stage of formal operations before he shows an understanding of this ability. The results indicate that

I. Q and gender have no significant effect upon hierarchial classification ability. However it was observed that mental age as an index of verbal ability significantly related to all measured variables, suggesting a relation worthy of future investigations.

Winn (1981) in his study concluded that diagrams can show representations of concepts realistically and the relationship between concepts in particular content area, especially how these concepts may be classified. That picture-word digrams are useful for teaching identification and block word digrams, help students learn classification schemes. The effectiveness of the pictorial and organizational aspects of digram appears to be related to learners verbal ability. Science teachers should therefore not use digrams and pictures indiscrimnately. The nature of itended learners needs to be identified with far more precision than has hitherto been the case in the design and use of science materials.

Rebecca (1974) in his study concluded that the manipulatory grouping experience is successfull in postively modifying the classification skill competence of young middle class caucasian children only in combination with teacher-child interaction. However both types of training are successful in inducing greater flexibility of grouping behaviour.

Simmons (1977) in his study concluded that (a) the performance of a psychomotor skill as measured by manipulations, was directly related to the method of presenting the definitions and to the amount of communication structure.

(b) The performance of a psychomotor skill as measured by the amount of time devoted to the manipulation task, was directly related to the method of presenting the definitions and to the amount of communication structure.

(c) The acquisition of knowledge about a psychomotor skill as measured by the test of multiple choice questions was directly related to the method of presenting the definitions and to the amount of communication structure. One can expect more proficient performance and longer student involvement in a task as well as more knowledge acquisition after an optimally structure and organised lesson than if student received a less well structured or organised presentation.

Researches found statistically significant effects of structure on knowledge acquisition. High structure produced high scores than low structure. Significant differences were obtained in the study, thus indicating that performance as measured by check list (manipulations) and (time) as well as knowledge acquisition as measured by the test of multiple choice questions, were directly related to the method of presentation and communication structure. Too much progression may inhibit performance and knowledge acquisition because the learner may fail to understand the nature of association among the isolated concepts or because the learner may fatigue from cognitive strain in attemtaing to supply the lacking association.

The correlation observed between test scores and the method of presentation supports "Gagnes" contention of task analysis", that best way to learn a performance task was by mastery of the subordinate phase which would in turn facilitate positive transfer to the subsequent higher phase.

It adds to the body knowledge which has acquired on kinetic structure. Moreover it is the first quantitative analysis of the affects of structure on learning a psycho-motor skill.

It provides evidence that the task analysis concepts aids the learning of a psychomoter skill.

The communication (high structure with definitions seperated) which was produced furnishes a useful tool for educators to employ in teaching this psychomotor skill

Verbal instruction could be employed to teach manual performance skills not only in science but in other subject areas and industry as well. Indeed it would be interesting to extend kinetic structured materials into an enquiry type of laboratory skill. For example will the advance presentation of a well structured psychomotor and conceptual introduction to a topic facilitate better student performance and enquiry than a less structured introduction.

Macbeth (1974) in his study concluded that the influence of direct first hand manipulative experiences in the developmen of process skills may well be more important for the early primary grade children than for older children. The children in "piagets" pre-operational" stage must operate on concrete objects. As they mature, children become less dependant on manipulative learning and more on verbal learning. Although this may not universally be true, it seems to be supported for the learning of science process skills.

Beaslay (1979) in his study concluded that the most interesting implication for science laboratory instruction was the equal effectiveness of mental practice when compared to techniques which utilize physical practice. Mental practice activities impose no great burden on laboratory resource and can be easily sequenced as a pre-laboratory exercise.

At present the scheduled pre-laboratory activities in freshman course tend to emphasize and reinforce cognitive learning associated with the planned experiment. On the other hand mental practice of manipulative skills required for the satisfactory completion of laboratory experiments offers a method whereby psychomotor learning may be reinforced. Any judgement about the value of such practice activities would need to be consistant with the course objectives and the stated importance of skillful laboratory performance, where a skillful laboratory performance is considered desirable The use of mental practice activities as a compulsory pre-laboratory student assignment may prove advantageous. Any experiment would need to be analyzed for inherent laboratory skills. Each skill would need to be described, illustrated and sequenced in a manner consistent with acceptable practice. These sequences would then form the basis of a mental practice pre-laboratory exercise for students. The nature of this mental practice exercise may vary from take-home free-laboratory assignments to slide tape or film loop observation exercise, where a skill is unfamiliar to students, teacher demonstration of the complete skill sequence prior to mental practice exercise may improve the effectiveness of the mental practice.

Doran & Dietrich (1980) in their study concluded that relationship among the three psychomotor variables were strong only for the MPFB* and Bennett pair. All four science classes and non-sciences groups showed significant relationship between I.Q. and Bennett scores. Relationship were strongest between the previous years science grade and the I.Q. variable and Bennett test.

Generally the physics students achieved the highest scores and biology students the lowest, while the chemistry and earth science students tended to score near the overall mean.

Cohen (1984) in his study concluded that teachers must be more than providers of activities and materials to students. They must take an active role, in that they should act as guides, encouraging the student to become as physically involved with manipulative materials as is reasonable. Further more a teacher should encourage a student to examine the materials from many vantage points and to utilize the materials in ways which seem appropriate based on the students apparent interests and levels of understanding.

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* MPFB stands for Minnesota Paper form board test.

Symmons (1975) in his study concluded that the investigation extends Anderson theory by applying it to the psychomotor domain. Anderson has designed a bridge linking learning theory which is largely descriptive with teaching theory which is predominantly prescriptive. ~~with teaching theory which is predominantly prescriptive~~. The more knowledgeable teachers, supervisors and teacher educators become about the process of teaching from a systematic view point, the more skilled they will become in developing a theory of instruction or at least a model of effective professional performance.

Spraglle (1977) in his study concluded that for the population of the study, increasing student verbalization during the manipulation of science materials did not significantly improve the immediate learning. It did however significantly improve the delayed retention learning.

Robbins (1978) in his study concluded that analysis of "blood components" lesson showed that it was more difficult in comparison to other similarly structured communications. More investigation is needed on the effect of lesson structure in interaction with different levels of lesson difficulty. Further study is needed to verify that no significant motor tasks between high structures and potency controlled structure lessons. Potency controlled lessons are compared to low structure lesson may be prescribed for general use in teaching manual tasks and scientific operative procedures.

Beasley (1979) in his study concluded that some form of planned practice of pscychomotor skills is more likely to be associated with a superior laboratory performance. However no differences were established among those techniques which emphasized physical or mental practice. Evaluation of the improvement gained through the planned practice activities must be made relative to the inherent accuracy of the applied laboratory technique.

The effect of Physical practice of "five" pscychomotor skills on chemistry students laboratory performance is moderated by the presence of mental practice.

Hymamra (1982) in his study concluded that for the population of the study demonstration with molecular models was equally as effective as having the students manipulate the models in increasing achievement over those who received neither demonstrations nor manipulations. This demonstrates the effectiveness of organised lecture demonstration oriented, additional sessions in improving achievement in organic chemistry and possibly reflects benifits from using molecular models in helpiing students gain a better understanding of the concepts. It could not be determined from this study whether manipulating or recieiving demonstyations with molecular models improves spatial visulization skills.

Data & Graphs

Yeany and Capie (1979) in their study concluded that the data processing observation guide (DPOG) has two potential functions. First it can be employed as a science teacher training tool. Whether the trainer engages the teacher in systematic analysis of models (e.g. video tapes) of data processing behaviour. This analysis assists the teacher in identifying, communicating and designing data processing learning activities. Accurately describing data processing learning activities. Accurately describing and systematically analyzing teaching behaviours allow teachers to bring their own teaching act under a greater degree of control.

The second function of DPOG is to assess classroom behaviour. In this function it serves as an assessment tool for research and programe evaluation. In order to serve as an adequate measure of the teacher student behaviour variable in classroom research, the reliability of indices derived from DPOG must be established. The initial results of this testing indicated that teachers who systematically analyzed their behaviour changed their teaching strategies in favour of more student operations when compared to a control group. On the basis of results from formative testing. The DPOG appears to have potential as both a research and teacher training tool in science education.

Cohen (1978) in his study concluded that the feasability of using kinetic structure analysis in prepearing criterion communications and examining their effects on knowledge acquisition in a quantitative way. A practical outcome is that high structured format for curriculum design has been found to be more effective than a low structured format for transfering of learning effects. A mental transfer model was proposed to illustrate the pathway by which the perceptions, storage and recall of acquired knowledge and its subsequent synthesis facilitates transfer of knowledge to a problem solving task.

Perpkins (1978) in his study concluded that students who have previously studied chemistry have better mathematics skills and do better in first quarter introductory community college chemistry than students who have had no previous study of chemistry.

Roller (1979) in his study concluded that Graph reading represented a difficult task, only a few high scorers reported using cues in text books to study graphs. Many more reported dependance upon content teachers to help them focus their attention upon graphs and to accurately extract meaning from the graphic format.

Mckenzee (1984) in his study concluded that:

(a) None of the instructional strategies examined appeared superior to others in regard to level of graphing achievement attained by students.

(b) Instructional strategies involving hands on activities resulted in higher achievement than the written simulation strategy.

(c) Transitional/Formal operational students tended to score higher than concrete operational students on the graphing achievement measure.

(d) Spatial scanning ability showed relationship to graphing achievement.

(e) The effects of treatment on achievement across levels of (a) cognitive development and (b) spatial scanning ability appear to have been consistent.

Staver & Halsted (1984) in his study concluded that in the same instructional environment, the effects of students reasoning levels are found in post-test sections that differ in the use of models and the cognitive demands of the items. Achievement may be effected by the format of the post-test. Thus teachers should carefully analyze their tests for the cognitive demands of the questions and use of manipulative, like the reasoning demands of tests must be analyzed and compared with reasoning levels of students.

Atwood & Stevens (1978) in their study concluded that this study provided no basis for the schools to engage in efforts to either increase or decrease student memory or questioning preferences for the purpose of improving science process performance in ninth grade.

Bady (1979) in his study concluded that apparently many students do not interpret implications correctly. Students who believe hypotheses can be adequately tested and proven by verification are likely to have a simplistic and naively absolutistic view of the nature of scientific hypotheses and theories. In fact any one who does not realize that scientific hypothesis can not be proven at all but only disproven can not be said to truly understand the nature of science. Perhaps the often reported poor understanding of the nature by many students results in part from their exposure to science without having developed the requisite logical skills.

Jones and Russell (1979) in their study concluded that a hierarchy when validated does represent a sequence set of intellectual skills. This sequences is probabilistic arrangement. It represents a probable expectation for a group of learners. A hierarchy does not identify the most efficient route for any one given learner. There are certainly possible variants in the hierarchy for individuals. The bright learner, because of past learning or innate capabilities may be able to skip over particular prerequisites. The hierarchial paradigm holds that when this happens the learner has been able to acquire a higher order skill by using a problem solving approach that probably also utilizes some very important strategies.

Hierarchies are not meant to slow down bright learners. Hierarchies should provide bases for finding more efficient paths for the majority of learners. Valid hierarchies should provide a diagnostician or the teacher with higher probalistics in their identification of where individuals or groups of learners fit in a hierarchy.

Neither does the use of a validated hierarchy dictate a teachers style of instruction. Nothing precludes teacher from starting on any spot in a hierarchy and moving his students "up" or "down".

It argued that the direction of a movement in a hierarchy distinguishes expository from discovery learning. In discovery learning, the learner is placed in a problem situation where he is unable to explain a phenomena. Through exploration he eventually discovers the solution. It further identifies a teacher starting with prerequistes and working up as the strategy follows in most expository classes. Paradigm does not insist on any specific sequence for instruction only the acceptance that there are necessary pre-requistes to the mastery of any super ordinary skill. If this condition is not effective learning should take place regardless of the instructional sequence selected. Perhaps this condition is one of the reason for our failure to identify differences in the effectiveness of different instructional types in past studies.

Populer & Wright (1980) in their study concluded that hypothesis forming behaviours can be taught effectively as part of normal classroom instruction. They also concluded that providing students with both of the criteria, acceptable hypothesis and differentiated reinforcements leads to an enhanced capacity to produce better hypothesis in new situations.

Aemil (1977) in his study concluded that (a) Differentiated reinforcement as an intensive instruction method is responsible for a higher quantity of written hypothesis after intensive instruction than the instruction method which involves no intensive instruction. (b) Participants who received intensive instruction which emphasized either differentiated reinforcement criteria or both generated a higher quality of written hypothesis following intensive instruction, than participants who received undifferentiated reinforcement or no intensive instruction. (c) No form of hypothesis generation intensive instruction improves the participants ability to generate a greater quantity or diversity of written information search questions following intensive instruction (d) Differentiated reinforcement. Only as an intensive instructional condition is responsible for a greater quantity of written hypothesis than no intensive instruction following the group discussion (e) criteria as an intensive instruction method is responsible for higher quality of written hypothesis, after the group discussion, than the instruction method of undifferentiated reinforcement or no intensive instruction (f) And in the presence of the group diversity of oral information search questions is not significantly improved by hypothesis generation intensive instructions

Eugene (1978) in his study concluded that scientists in their inquires engage in a two component complementary operation hypothesis generation and hypotheses testing. Based on positions taken by science educators it is concluded in this study that science teaching should reflect the practice of science when a current view of science teaching is examined, however it is found that there is an over emphasis on the testing component at the expense of generating component. A major reason for this imbalance is that characterstics of the testing component are already in a form (the mental operation inherent in the process of induction and deduction) which is translated to science teaching.

Ziethor [redacted].(1981) in his study concluded that the type of practice involved during instruction of the communicating skills seemed to have little or no influence on subjects acquisition of the skills. Both groups seemed to acquire the skill equally well. They also concluded that the type of practice had some influence upon the number of communicating skills incorporated in a subject teaching plan. Subjects who practised through micro-teaching incorporated the skills more frequently than subjects who practised through modelling. The subjects who practised with micro-teaching were more effective instructors than those who practised with modelling.

Hofstein, zvi, & Samuel (1979) in their study concluded that (a) high school students mean score on the critical questioning area was significantly higher than that of laboratory technicians and post graduate students.

b) The preference of both postgraduate and science club students for the application was lower than that of high school students.

c) High school students differed from other three groups in their low preference for "recall"

d) Postgraduate students as a group were found to resemble the science club students in their preferences

Krieger(1982) in his study concluded that there appears to be no significant difference between the written test scores mean and the laboratory performance test score means when used to measure very specific skills(i.e. ability to take data from graphs and or instrument scales. Because of the problems with meteric drift etc, the paper pencil analog test may be seen to be superior to the *LPT and so is more time and cost effective. The LPT might be better utilized in measuring other aspects of laboratory experience.

Johnson (1976) in her study concluded that Emperical formulative evaluation of student performance demonstrates that learning to ask research questions is useful tool for developing and investigating research questions skills in students. A generally high level of performance was obtained with indicators that taxonomic questioning is easier for students than cause effect inquiry. Tests of hierarchial validity suggest that the relationship between pairs of skills is hierarchical in nature. In addition the students developed a questioning strategy in the course of the eleven lessons, an aspect of questioning behaviour which merits further exploration.

Eisenberg(1976) in his study concluded that students with low cognitive skills can be taught to function well in areas requiring psychomotor skills. The study also revealed that females did not remain in the job as long as males and that former students did continue their education. The programme was an effective alternative form of education.

*LPT stands for laboratory performance test.

Bolesky (1977) in his study concluded that (a) students using calculators to perform routine calculations during class room sessions of a "CHEM-STUDY" chemistry course do not achieve significantly higher score on chemistry achievement tests than students who do not use calculators during class room sessions (b) students from a "Chem Study" Chemistry course using calculators to perform routine calculations on chemistry achievement tests do not achieve significantly higher scores in chemistry achievement tests than students who do not use calculators during chemistry achievement tests.

Jantaraweragul (1978) asserted that (a) cognitive style in terms of a factual concept set is not reflected in differential skills in any of the basic science processes (b) one's attitude in reference to the student or teacher as the centre of instructional activity is not related to one's skill in any of the basic science processes (c) Cognitive style and student teacher-orientation attitude do not intereact in the demonstration of skill in any of the basic science processes.

Davidson (1978) argues that both short term achievement and long term achievement were similar for the two feed backmodes since student perference was not a factor, and since laboratory time favoured the competency measure mode, the investigator chose competency measure mode as the more satisfactory way to provide feed back in a laboratory course.

Ozsogomonyan (1978) found that (a) Most underprepared students are able to master important chemical concepts ordinarily taught in a freshman chemistry, if they are provided with individualized programmed instruction and allowed to proceed at their own pace (b) underprepared students will respond much more favourably to individualized instruction, if interaction with course manager is maintained.

Ward (1979) argued that (a) Formal students show higher achievement on test items requiring concrete thought than do concrete students. (b) Formal students out perform concrete students on test questions requiring formal thought. (c) A limited exposure to the learning cycle in laboratory instruction does not appear to improve the performance of concrete or formal students on test-item requiring formal thought. (d) concrete and formal students show similar levels of achievement on test items which require only recall of facts or formulas. (e) Intellectual development appears to be an important factor in the design of general chemistry instruction.

However it is still uncertain as to how instruction might be altered to make it amenable to concrete students and at the same time still includes all the concepts necessary in a first course.

Hartford (1980) claims that the pretest enhanced the post-test performance of the experimental treatment group. However it diminished the control treatment groups post-test performance. By analyzing the post-test scores of un pre-tested students only, the experimental treatment effect was found to be statistically significant accounting for 14% of the variance of the post-test scores. However, the level of intellectual development had no effect on these post-test scores. The lesson developed in this study, when used in the on-going laboratory programme enabled high school chemistry students (of general and advanced ability levels) to ask more and better research questions. The Piagetian level of intellectual development of the students does not affect the effectiveness of this instruction as measured by research questioning ability instrument used in this study.

Adkins (1980) finds that (a) Mental imagery ability appears to play a more active role in the learning of the atomic-molecular models of the atom than in the learning of the gram-molecular mass concept (b) classification skills, science word recognition, ability and interpretation of data skills affect the learning of atomic theory more than imagery ability (c) Imagery ability appears to influence the acquistion of science process skills, but its affect is moderate (d) Imagery ability has relatively little relation to overall science aptitude as measured by the comprehension test of basic skills. (e) understanding of the gram-molecular concept in chemistry is mainly facilitated by a students mathematical ability. (f) interpretation of data skills as measured by the comprehensive test of basic skills is an effective predictor of science achievement within the scope of this study.

Bachuroff (1980) showed that scientific laboratory experience did enhance the cognitive development for the eighth grade subject. This was not shown for the seventh grade subjects.

Brooks (1982) in his study concluded that no significant differences were found in levels of achievement between mastery and non-mastery average or above average students. Above average mastery instructed subjects scored significantly higher than their non-mastery counterparts on an instrument measuring retention of low level process skills but average mastery instructed subjects did not show any significant differences in retention from non-average non-mastery subjects. Both average and above average mastery instructed subjects scored significantly higher than their non-mastry counterparts on an instrument measuring rentention of low level process skills, but average mastery instructed subjects did not show any significant differences in retention from average non-mastery subjects. Both average and above average mastery instructed subjects scored significantly higher than their non-mastery counterparts on an instrument measuring retention of higher level process skills. While mastery instructions may not be significantly better than non-mastery instruction in effecting achievement gains when equal amounts of time are spent in both modes of instruction. The mastery instruction strategy can sometimes produce a more permanent mastery of sequentially organised materials (higher process skills) than an equivalent time-non-mastery instructional stretegy.

Newton (1982) asserted that the level of students planning is significantly associated with process skill achievement, even when the formal reasoning ability of student is considered. Student generalizing is also significantly associated with process skill achievement but not when formal reasoning ability is considered. There were no significant interactions between the engagement modes of interest and student reasoning ability.

Muh (1982) found that there was some transfer of the reasoning skills to novel problem solving situations with college students. In addition, the research data showed that there was a positive correlation between cognitive growth and field dependence, Independence cognitive style, and field indepdnent cognitive style was one factor predicting achievement level of hypothetic-deductive scientific reasoning.

Spickler (1984) claims that laboratory exercises can strengthen intiution leading to improved student comprehension of related concepts. Intiution improves information processing skills of the intellect in a surprising way.

Mcmeen (1983) in his study concluded that:

a) Both students who had a exposure to a traditional chemistry programme and students who had an inquiry oriented laboratory based chemistry programme showed equivalent increases in intellectual development as measured by the TOLT* test.

b) Significant positive correlations were found between the pre-test TOLT and final course grade and between post-test TOLT and final course grade. There was

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* TOLT Stands for Test of Logical Thinking.

found to be a significant higher correlation of the post-test TOLT experimental group scores with final course averages.

Valdesolo (1983) concluded that: a) Hypothesis formation is a process skill that can be p improved through training.

b) Improvement in the ability to formulate scientific hypothesis was equally significant among bilingual and monolingual students.

c) Billinguism has a significant effect on the ability to formulate scientific hypothesis at a level where students are highly proficient in both languages (Italian & English).

d) Billingusim has no significant effect at a level where students are proficient in second language but not in their first or are highly proficient in their first language but not in their second.

(V) Recent Advances in Laboratory Instruction

Now let us take the issue of Recent Advances in Laboratory instruction. Many Advances have taken place in the western world.

Computer Assisted Instruction

Rao (1975) stated that "Computors are most commonly used by chemical educators to simulate physical or chemical systems as problem solving aids, to analyze, experimental data or to familiarize students with programming. On line-computing and digitization of data and the like. Some centres have a large number of computers located near classrooms, laboratories library carrels and dormitoecees.

Several teachers around the world have been training under-graduate students to use computors to solve chemical problems. Courses are taught in numerical methods in chemistry on line computor applications in analytical chemistry and instrumentation chromatography and other subjects like on line gas chrinatography and kinelies. With the recent developments in electronics it is now viable to collect data for many chemical experiments in digital form not only are digital data very accurate but they are readily processed by computors. It is therefore important that students become familiar with digitization of data during their undergraduate or postgraduate training.

Interactive on line computing provides the student with a capability which enables him to carry out sphosticated mathematical operation with a single key board display console students can handle problems involving mathematical models and simulate experiments. Simulation provides rich experience in the analysis and presentation of data and in making hypothesis. Students readily work out orbital contours, rotation spectra, theortical NMR spectra, probability diagrams etc. using the computor. Even without a detailed knowledge of the mathematics involved "Qualitative" computing involving graphical display of some aspects of chemistry such as orbital contours is still very useful. Laboratory equivalent computer experiments such as aid-base titrations or gas laws are performed in some centres. Computor based simulation of laboratory problems in qualitative chemical analysis has been reported.

Computor animation provides a new insight into the study of molecular vibrations, inter-molecular interactions and other complicated processes. Computor animation of reaction pathways provides an understanding of how reactions occur. Computor assisted instruction (CAI) has been attempted in many centres with varying degrees of success. CAI allows individualization of instruction under the control of a teacher. It takes advantage of the rapid retrieval capabilities of time sharing computors operating in a conversational mode and employs specially constructed languages to develop programmes that can conduct a rich dialogue with a student. The logic of the dialogue is contained within the control words in the language. The terminals on which students obtain CAI can be located anywhere. CAI has been used to manipulate experimental data simulate experiments and to provide remedial or drill programmes at various levels of undergraduate education.

Computor assisted instruction in the physical chemistry laboratory has been found quite satisfactory and somewhat superior to conventional or programmed instruction. Chemical reaction stoichiomatry, instrumental analysis and radiochemistry have been taught through CAI. CAI in organic chemistry has been quite successful; organic reaction qualitative analysis and organic synthesis have been incorporated in such programmes. In CAI in organic chemistry the decisions and actions of the students controlled the progress and the students were directly involved participants.

In spite of the variety of experiments in CAI, the revolution in the classroom predicted by its staunch proponents has yet to take place. There is still considerable scepticism among teachers as to the future role of computors in education. Industrial forms with competence in CAI seem to be adopting a wait & see attitude before a developing the products any further. Some have expressed the fear that computor aided instruction may become mere programmed instruction unless considerable care is exercised. The following guidelines are suggested to be kept in mind while employing CAI. (a) built in provision for teacher student interaction (b) opportunity for the student to exercise his own initiative and possible computor recognition of the initiative (c) possibility of slightly different responses for the same input.

Cavin & Lagowski (1978) in their study concluded that the students in simulation groups generally achieved as well er as better than students in the laboratory groups, the possibality of using a simulated experiment in place of a laboratory experiment in some instances in a college chemistry laboratory, as was previously indicated for high school laboratories is supported.

The best use of a simulaation to teach a procedure with an instrument would be as an introduction in which the students could become familiar with important procedural steps, some of which may be overlooked in the laboratory since it is usually impossible for the laboratory instructor to drill each student individually on instrument use.

The comparison of scores showing possible interaction on tests in two groups is in agreement with previous results at the elementary level indicating that computer simulated experiment may be especially useful for low-aptitude students, both as laboratory expriment substitute and as a supplement while still being a satisfactory means of instruction for higher aptitude students.

Moore, smith & Avner (1980) argues that Interactive instruction provided by CAI*appears to

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* CAI stands for Computor Assisted Instruction.

significantly facilitate laboratory performance in situations where students must understand the operations well enough to interpret intermediate results and to decide alternative actions based on these interpretations. If the laboratory is so highly structured that the student is able to operate without understanding what is happening no advantage is likely to be seen in using interactive instructional materials.

Starkey & Kieper (1983) claims that the objective of pre-laboratory quiz system is to help optimize each student's educational experience and safety in the laboratory by assuring that students come to the laboratory sessions adequately prepared. He further concluded that an adequate laboratory preparation should improve a students understanding of and efficiency in performing the laboratory experiments and in addition increase laboratory safety. Anxiety towards the laboratory should be reduced when students know they are adequately prepared before coming to the laboratory session.

Jones (1980) showed that pre-laboratory Video-tapes are most helpful when they describe the steps in a procedure with which the student is most likely to need instruction when they show the stimuli indicative of correct performance and when they include magnified views not practical in a class room demonstration. In all cases the successful videotape presentation are the simple ones which exclude irrelevent materials.

Wise (1984) in his study asserted that

(a) Both pre-laboratory and post-laboratory micro-computor simulation strategies result in higher student achievement than conventional laboratory instruction. This difference occurs on achievement above the knowledge level. While each of the instructional strategies employed in this investigation results positive student attitudes. Pre-laboratory simulation or conventional laboratory instruction produce the most postive attitudes.

b) Higher aptitude level students out-achieve lower aptitude level students.

c) The effects of the alternative instructional stretegies are consistent across aptitude levels.

d) Student engagement does not differ across the instructional stretegies investigated.

e) The micro-computor simulation strategies are useful in extending the total instructional time devoted to a set of objective.

f) Micro computor laboratory simulation can be successfully implementated in the class room from the stand points of practicality, equipment requirements and software production.

Ploeger(1982) in his study argues that a computor programme simulation was effective in teaching science class room laboratory safety to preservice teachers.

The study also demonstrated that the subjects transferred the ability to correctly recognize and prioritize safety hazards in another simulated science class room laboratory settings.

David (1982) in his study asserts that:

a) Simulation were as effective as, but not significantly more effective than the "live laboratory experiments in improving student skills in genetics analysis.

b) Simulation can be used very effectively as a back-up system in case "Live" experiments can not be performed. Finally this study suggests that further research should be conducted on the effectiveness of computor simulations with students who are taking cour ses that are compressed into short time spans.

Bobbert (1983) in his study concluded that different interactive computor simulated experiences were as effective an instructional activity as actual laboratory experience for the subject material tested. For the Boyles gas law experiment, students who did both laboratory work and experienced the computor simulation scored significantly better on their post test than those who experienced only the laboratory or only the computor activities. No statistically significant difference was shown between those who did ~~nt~~ only the laboratory work and those who did only the computor simulation.

In an attitude survey most of the students considered the interactive computor simulated exercises as an acceptable learning methodology and over half expressed a desire for more of these activities in future laboratory work.

Choi (1985) in his study asserted that computor simulated experiences could be used in place of hands on laboratory experiences with an expectation of equal performance levels by students in approximately one half the time required for the hands on laboratory experiences when covering certain topics in secondary school science. Another implication of this study was that a computor programme could be used to replace more expensive instrumentation or materials in many traditional hands on laboratory experiments. Computor simulation in science education could be efficient and cost effective as well.

Television Laboratory Instruction

Driscoll (1974) in his study argues that:

a) The hypothesis that a general education student can gain an appreciation of the experimental nature of chemistry seems to have been achieved to at least to some degree.

b) The hypothesis that a general education student can be developed to create a favourable response by the student while maintaining a standard level of sphostication in an academic content in the course also seem to have been achieved. The evidence for this is the content evaluation by the panel of experts and the appraisal by the course instructors.

c) The hypothesis that there would not have been any significant difference in achievement as measured by chemistry tests between groups that were exposed to the tapes and the groups that were not was validated by "t" test results.

d) The results of this study tend to support the contention that instructional quality can be continually improved. Continuing feed back from different sources in this study demonstrated in a quantitative way that quality can be improved and would imply that higher level of performance could continue with each of this type of analysis.

e) Although this study did not include an analysis of laboratory skills, the experience with the laboratory sheets seems to indicate that the students vicariously prodeeded through the usual steps of the inductive approach.

f) The experience of this study suggests that teaching improvement can be enhanced by analysis of teacher performance using the approaches suggested here which are similar to micro-teaching.

Ganz (1975) in his study asserts that the addition of television, as a substitute for an audio-tutorial presentation, does not justifiably improve the performance of the students in the laboratory nor does it appreciably affecte their desire to use that laboratory, as measured by their attitudes.

Kaplan (1982) claims that boys and girls already interested in investigative science responded positively to role models. Second, girls who exhibited masculine traits and perceived masculine traits less stereo typically were more receptive to female role models. Third, although boys and girls liked same sex models appeal of and attitude towards female models diminished from beginning to end questioning the effectiveness of these selected role models. Reasons were related to appealing and non-appealing aspects of personality verbalizations, appearence and behaviour/activity.

Therefore if role models are to be the vehicles to interest more girls in science, careful attention needs to be focussed on personal qualities of the role models. Furthermore, understanding more about the target population of boys and girls, their initial interest in investigative sciences, sex role sterotypes and other attributes would lend to greater effectiveness of female role models.

Video tape casettes assisted laboratory instruction

Sherwood & Gobel (1980) asserted that the use of audio tapped problem solving sessions appears to be an effective method for discovering how subjects solve problems. The use of pre-designed behaviour classification scheme, such as the one employed in this study, makes possible the discovery of problem solving behaviours and strategies of individuals and groups. Statistical analysis of these data can provide evidence of the common problem strategies used for different types of problems by subjects who are already effective problem solvers.

Two further lines of investigation in this area of effective problem solving are currently being pursued. An analysis of the behaviours and strategies used by non-successful problem solvers group in this group is being studied is being conducted in an attempt to discover the specific deficiencies represented. In addition we are investigating instructional methods and materials that might be used to make the non-successful problem solvers group more effective problem solvers.

Ferraro (1983) finds that one of the most frustrating experiences for a student who arrives for the first time in chemistry laboratory is being faced with new instruments and laboratory techniques that he or she has never dealt with before. Furthermore typically the only introduction to the laboratory is through the prior reading of book and/or a brief explanation by an instructor at the beginning of the laboratory. The purpose of this project reported here was to provide a Video-library related to laboratory instrumentation and techniques which would assist the new student in learning these techniques and to make his/her first contact with them in the laboratory less disappointing.

In General students feel that the tapes have significantly improved their effectiveness in the laboratory because they can work with more speed more confidence and with less help of the instructor. Specifically 98% state that the programme have been at least useful or very useful, 65% think that the tapes are very well realised and 35% that they are well realized and 90% agree that the project should be extended to a larger number of programmes.

Evams (1979) concluded that no significant differences in multiple choice measures of knowledge comprehension, or application scores as a function of different orders of presentation of or different levels of discrepency for a video-taped demonstration of an experiment in science.

Rivero (1984) argues that data obtained from the "attitude" questionaire indicated superiroity of the audio-tutorial method in the areas of student motivation and involvement and use of reinforcement strategies. Students also benefitted from preciseness of the instruction, procedures and accommodation to perform individually.

<u>Filmed (Experiments) Instruction</u>

Zevi, Hofstein, Samuel & Kemps (1976) in their study asserted that excepting the manipulative skill area film loops showing experimental situations are an effective substitute for students individual laboratory work in that they do not effect adversely cognitive or laboratory based problem solving achievement. In the area of routine manipulative skills, direct experience of laboratory work obviously leads to a higher performance level but the relative advantage gained by experimental group students over film group students is small and points strongly to the potential of filmed experiments as means of teaching manipulative skills.

In the light of the present study, the conclusion is justified that well designed films or film loops are a viable alternative so student based laboratory work, especially in situations where as the result of administrative, economic or time problems, a truly laboratory oriented approach to chemical Education is not readily implemented.

Zevi, Hofstein, Samuel and Kempa (1976) in their study argued that the results indicate that the two approaches are equally effective in terms of the cognitive and to a considerable extent psychomotor outcomes, resulting from them it is clear from the present data that this does not apply to students perceptions of the approaches and their liking for them. Students rate the educational value of the medium based approach to laboratory work as being distincitvely less than that of personalised experimental work, likewise they give a low preference order to filmed experiments among different modes of instruction experienced by them.

The results of this study confirm and to some degree extend the findings of other workers who have reported similar attitudnal effects to be associated with film & T.V. teaching. There clearly exists a problem concerning the long term acceptability of a medium based approach to teaching, even if this is employed in only a limited section of students total educational experiences. However findings of this nature reached in comparison with "conventional" teaching approaches should not be used to judge medium based approaches too harshly. The authors are convinced that they have a great deal to offer, especially in situations where the implementation of "conventional" approaches proves difficult or impossible for whatever reason may exist.

Photo Micrography

Ali (1984) in his study argues that group I students taught by lectures with photo micro-graphy used as an adjunct to the laboratory attained the highest post-test mean score. Group II students taught by lectures with laboratory came next on the post-test mean score. Group III students taught by lectures alone obtained the least post-test mean scores. The data indicates that the differences in performance demonstrated by the three student groups of this study was not due to chance but was an outcome of the microbiology teaching learning they expected. 94% of Group I students expressed the feeling that photomicrography used as an adjunct to the ~~lab~~ laboratory was most motivational teaching-learning mode for micro-biology when compared to laboratory or lecture mode of instruction. 87% of group III students perceived lectures as boring and non-motivational teaching learning mode for the study of microbiology. Group II students came next on the response. The motivational indices were 0.81, 0.52 & 0.13. There was no difference between the three modes of instruction in the use of scheduled time (actual teaching time). Efficiencies in three modes of instruction were same.

The cost of introducing and photomicrography teaching technique was the most expensive teaching mode compared to laboratory or lecture teaching mode.

Colour photographs

Tarcza (1978) in his study asserted that the incorporation of colour photographs into laboratory guides did not enable students to perceive as less difficult the setting up and performing of physical science experiments. However in complex task requiring much information, students with colour photographs tended to seek less assistance from an instructor. Also in some experiments students with previews tended to form fewer partnerships.

Modular System

Howard (1980) argues that students in clinical micro-biology frequently experience problems in integrating didactic information with practical laboratory experience. It is difficult to conceptualize long text book descriptions of morphological and biochemical characterstic of insects. As a result students may not be able to apply the material to clinical laboratory situations. This dissertation addresses this problem through a series of modules or auto-tutorial curriculum packages in clinical micro-biology and development of laboratory skills.

Clinical reasoning

Heller (1980) asserts that the tutors ability to diagnose student deficiencies varied as a function of the specific subject matter that was the focus of interaction. Rendering a correct diagnosis did not always eliminate the students deficiencies. Student opinion data showed that these tutors were well liked and appreciated even by those students who continued to exhibit knowledge deficiencies.

The data suggest that valid representation of the tutors models of course chemistry knowledge were developed and that the reports by the tutors during stimulated recall are probably a combination of accurate recall and post-hoc reconstructive explanations.

Anderson (1984) asserted that there has always been an emphasis on theortical knowledge and technical skills in developing competency in a clinical science laboratory curriculum. Elements of the effective domain such as attitudes, values, feelings and emotions have been overlooked. We continue to allow students to learn most of their attitudes through a latent curriculum primarily through role models. Attitudes are an integral part of the clinical laboratory science profession. Competent professional practice integrates the cognitive, psychomotor and affective domains. If any more component that makes up competency is deficient or inadequate, the quality of practice would be diminished.

The goal of the intervention was to address the effective domain and thereby develop a professional attitude in the student. It was anticipated that the frequency of errors occuring during the performance of laboratory determinations would decrease as a result of intervention when compared to a base line error rate established by the control group. A multivariate analysis technique was employed to analyze the data from the diagnostic test results. This analysis yielded a "p" level of 0.70 for the treatment effect. Since the alpha was present at 0.05, the null hypothesis that stated that no difference existed between the treatment and control groups was not rejected.

Arnold (1975) in his study concluded that in general the results of his study agree with reported literature that relative to educational methods, there is need for change, possibly a change towards individualized instruction. However extensive research should precede any such change.

Case (1980) argued that :

a) Individualized laboratory instruction had a positive effect on initial enrollment.

b) Individualized laboratory instruction increased the retention of students.

c) Individualized instruction improved students achievement.

(VI) Factors Affecting Laboratory Skills

Let us examine the factors which affects the development and retention of laboratory skills.

Keeves (1975) asserted that achievement and attitudes are inter-related. Those components of attitudes which have been measured in this inquiry are strong and are largely independent of achievement. In seeking to identify the major forces in the educational environments of the home, the class room, and the pear group that influence final performance, after allowance has been made for initial performance, it is necessary to bear in mind these relationships between achievement and attitude. It is important to recognize that some environmental factors are malleable and open to deliberate modifications while others are not. We find that the antecedant conditions - - - -

are strongly related to the structure, attitudes and processes of the home. The initial achievement and attitude of the student as well as sex of the student influence in part the attitude and practices of the home in which the student lives. The attitudes and ambitions of the parents for the students although dependent on the past performance contribute to the final level of achievement in science. Home practices including relationship between the home and school etc. make significant contributions to the achievement in science. The clustering together of factors influencing the performance of the student at school and suggest that changing any one factor may not produce a marked factor, but where more educative environments are established in the home, the class room, and the peer group, the cumulative effects may be substantial.

Mathis (1977) argued that it is important to carefully select for inclusion in the curriculum those products which (1) create student interest (2) Maximize process skill development (3) provide a frame work for future learning and (4) have practical application in a wide variety of work situations and at home.

In justifying vocational curricula, a great stress is placed on the value of practical knowledge and skills.

The rationale emphasizing the practical usefulness of vocational studies has strong appeal in today's pragmatic society. It is not inconceivable therefore, that studies presently considered vocational may in future be regarded as general education subjects and a consequence be accorded a more fundamental role in the overall curriculum.

Erikson G.I. & Erikson L.J. (1984) concluded that boys outscore on items which test understanding of scientific knowledge and application of such knowledge. This is specially evident on the physical science but only barely so in the biological sciences. In the area of process and processes skills which included items testing understanding of the logic of scientific reasoning there were no sex differences. Enrolment pattern in the senior science courses had a very limited effect upon the difference in performance between the sexes. Evidence for biological position is as yet weak and that at best a biological interpretation is cm incomplete. Socio-cultural factors are working to give boys an early experimental advantage in many science areas. Evidence for the experimental hypothesis was not only drawn from the fact that sex-related differences in science scores are apparent before the age at which the spatial abilities differences are generally recorded but it was also illustrated in a number of individual items which test knowledge in areas more typically encountered in a boys sphere of experience. We conclude from this analysis that the sociological interpretation had greater educational potential. In the long run the most effective approach to the problem of girls and science is not to regard girls as a special (inferior) species of the learner in science but to acknowledge the role of experience in learning in science class rooms and to develop means to compensate girls for their lack of experience.

Type of School & Home

Stronck (1974) asserts that the data supports the hypothesis that specialised science teachers typically found in larger schools do provide better instruction than that which can be provided in small schools. The employment of the head of the household in which the student lives sometimes is related to achievement of the students. If the head of the household has had the means of education, training required to become a professional, the student will probably have high achievement. On the other hand if the head of the house-hold is unskilled or employed outdoors the student will probably

will have poor achievement on the science test.
An environment of the scholarship in the home certainly favours high scores.

Lo, Lamfat (1982) asserted that while majority of the selected student and teacher variables significantly influenced science achievement, none of the selected home back ground variables were significant.

School Activities

Doran & Sellers (1978) asserts that by way of divergent open ended laboratory experiences students are allowed the freedom to manipulate, explore and concentrate on the materials that capture their imagination. As the students are actively involved in a decision making process, their learning becomes self-appropriated. Knowledge and information gained in such a situation is meaningful in that the students have part of themselves riding on the outcome of the experience.

Science Museum

Flexer & Borun (1984) argued that the particular strength of the science Museum exhibit lies in the affective domain. Students found the exhibits much more enjoyable, interesting and motivational than a class room lessonl They can be assured that the museums experience will stimulate an interest in learning science concepts by presenting them in a manner that students find exciting. Science Museum by providing exhibits which generate enthusiasm for and interest in learning science can serve as a valuable adjunct to formal science education.

Places of Scientific Interest

Koram, Longino, & Shafer (1983) in their study concluded that Natural history museums, science centres, zoos and Aquaria contribute considerably to out of school experiences for visitors of all ages and characterstics. With birth rates and school age populations declining, it is likely that people will be looking to these settings for rest, recreations stimulation and learning. Science educators can play a leadership role in research, development and in utilization of these settings to achieve learning and motivational objectives which support, supplement and extend school science learning. But what is the current "state of Art" in this area. This article reviews relevant past studies, proposes a taxonomy of exhibits in museum settings and focuses attention on facotrs which should be considered when studying learning in these settings. In addition it presents some potentially productive methods of conceptualizing research and suggests possible future lines of research for the science education.

Socio-Economic Status

Fraser (1980) in his study concluded that since socio economic status was measured in the present research solely in terms of parental occupation, the observed magnitudes of correlation should be viewed as lower bounds to estimates likely to emerge in research employing multiple indicators of socio economic status (e.g. Parental Income, education, attitude towards school and aspiration for the child's education). Consequently the relationship between socio-economic status and enquiry skill proficiency found in this study should be sufficiently strong to cause some concern among science teachers. In particular since low proficiency at certain enquiry skills (using reference materials, interpreting graphical information) could restrict students ability to benefit from science learning experiences. It is possible that the lower levels of enquiry skill proficiency among students of lower socio economic status ultimately could hamper progress towards achieving other aims of science education. Fortunately however enquiry skills can be directly taught to students who have been diagnosed (perhaps through use of an instrument like the test of Enquiry skills) as having low levels of enquiry skills proficiency. Therefore by conciously striving to overcome enquiry skill deficiencies science teachers might be able to enahcne achievement of other aims among students of low socio economic status.

Effect of Sex

Squires (1977) concluded that verbal abilities of girls is generally better than the boys ability according to the research done in the area. The science problem solving in this study was in verbal form. It has been further shown that verbal skills make a difference on verbal problem solving. This study supports this finding. It is concluded that verbal skills (reading ability) caused the results of the science problem solving scores of the females to be higher than the scores of the males.

Donovan (1982) concluded that (a) Eighth grade science teachers as sex role models did not enhance Science Education career interests of their students and (b) Eighth grade girls Science Education career interests were not influenced by science teacher sex or teaching effectiveness

Cognitive Style

Cognitive styles had significant variance in this study, that is the field independent were significantly higher in science problem solving than the field dependent subjects, but there was no correlation with any of the other variables that was significant.

Therefore it must be concluded that for study cognitive styles was not a factor in science problem solving.

Beane (1977) argues that interaction between the mastery needs, work orientation and competitiveness aspects of achievement motivation were found to strongly affect criterion performance, suggesting the need to view achievement motivation as a multi-dimensional constellation of traits. High levels of competitiveness were found generally to suppress performance. This finding was discussed in terms of the effects of high competitiveness on scientific research behaviours.

Only two life history variables, social status and social competency related strongly to the criteria with high performing scientists coming from less affulent backgrounds and being more socially introverted during adolescence. Prior academic performance was unrelated to the criteria with regard to relationship among predictors. Masculnity was found to be negatively related to social status and postively related to social competency and academic performance during adolescence. Feminity was related only to social competency, with highly feminine scientists reporting higher social competency during adolescene. Social status was found to be negatively related with achievement motivation with highly competitive indivīduals coming from less affulent backgrounds. Social competence and academic performance during adolscence were generally positively related to the achievement motivation factors but there was a lack of relationship between the parental murturence variables and later achievement motivation. One possible explanation for this was advanced in that since the scientists scored subsetantially higher on achievement measures than a comparison group of undergraduates, they represent the higher end of an achievement motivation distribution making relations harder to identify.

Masculinity was consistently related in a positive fasion to all the achievement factors, although faminity was related only to personnel concern. This finding was discussed in terms of the types of achievement behaviours required of academic scientists.

Regression analysis on the scientific attainment criterion using a pool of life history and personality items, yielded a multiple R of 0.40 accounting for 16% of the criterion variance.

Maceurdy (1979) asserted that there are over 100 items that build the potrait of the superior science student. The potrait is a complicated one, so each general category of the potrait has been reduced to a few general characteristics. These have been developed by combining and consolidating several items in the category to a single quality (personality, Attitudes and opinions, Interests, Activities, Family history, Associates, Science teacher, Decision to be scientists and review).

Taitt (1981) argued that in the last centurary, scientific technology has played a major part in altering the way of life for the persons in the United States. The need for more persons with a knowledge of this technology is growing rapidly. The job of training these persons rests mainly with the colleges and universities, across the country.

<u>Hobby Influence</u>

The concept of hobby oriented physics experiences involves coupling the high motivation present with hobbies to the concepts of physics that the teacher wishes to present. Recommendations for introducing this concept into an existing class are included along with suggestions for creating physics individualized experience (P.I.E.) which aid in the transition for teacher oriented to student oriented learning.

<u>Laboratory Instruction (Handicapped)</u>

Linn (1979) argues that communication skill might be enhanced more in a resource than in a mainstreamed situation. The activities can be conducted with maximum student interest in and likely student cognitive gain.

Mansfield (1977) finds that general and specific findings were noted for each educational level. There were statistically significant differences between the experimentals and controls in both multivariate and univariate analysis of the data. Both perceptual ESS* units and psychomotor ESS units were found to improve at least one of the three science skills in some educational levels.

There was an increase in the frequency of mean verbal expression scores and the frequency of mean observations made by students. There was a corresponding decrease in the mean frequency of inference made by students from primary through senior high. In combining all educational levels (primary, Intermediate, Junir high, senior high) the experimental group displayed a significantly higher frequency in mean verbal expression and mean observation scores. There was no significant difference between the experimental and control groups in the mean frequency of inference. In general EMR** students exposed to ESS units demonstrated a higher level of verbal ability.

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* ESS Stands for Elementary Science Study

** EMR Stands for Educable Mentally Retarded.

Waskoskie (1981) in his study showed that based upon the work of swiss psychologists Jean Piaget researchers have discovered that upto 50% of college level students are concrete operative thinkers. This means that they must have "hands on" experiences to gain concepts. Blind students lag behind the sighted students in their mental development as much as 8 years. This means they remain concrete operational thinkers for longer periods of time than the sighted students. Blind students therefore need concrete experiences to gain concepts.

The results of the laboratory sequence, however strongly suggest that the mutually reinforcing combination of verbal interpretation and explanation along with the actual experience offered by the models and specimen produce the ideal environment in which to have hands on concrete experiences. The laboratory session in an introductory biology course need not be vicarious experience for blind students.

(VII) <u>Evaluation of Chemistry Laboratory Instruction</u>

Taking the issue of evaluation of laboratory instruction, let us examine the relevant literature.

Hofstein, Gulzman, Zevi & Samuel (1980) in their study argued that the laboratory is a democratic and satisfying environment in which students can work and learn freely and less competitively. Most of their learning is based on information obtained from laboratory activities which might be a difficult task. They learn in small size classes. Students found their learning environment less difficult because students were better able to conceal low personal productivity. Competitiveness can lead to high anxiety, extreme vivacity and hostility and feelings of failure and isolation. Under certain classroom environmental situation the competition between students appears to diminish. It ufxk further argued that "We are already facing a trend in which there is a retreat from student centered science activities resulting in a decline of time and experience in the science laboratory". One of the reasons for this trend may well be the failure of existing research studies to support the value of laboratory work as a medium for effective learning. The laboratory is an important vehicle for influencing students perceptions of their learning environment.

Doran (1978) ins his study asserted that the relative stress on manual skill development in science programmes is still a moot question. Each science teacher will differ in the emphasis he gives to the students equipment manipulation and laboratory technique. Research into psychomotor aspects of science laboratory objective is woefully lacking. There are presently no universally accepted criteria for describing a students science laboratory skills. It further concludes that major problem is "to find ways of developing much more detailed and precise specifications than have hereto force been attempted of the behaviours that the student is to attain. These specifications would also delineate the prerequisite behaviours leading to the desired criterion behaviour gx so that the student who has not attained mastery may be given soundly based guidance.

Further study and analysis of psychomotor behaviours in science education will likely have a postive impact on curriculum instruction and evaluation. Inquiry into this concern should stimulate more philosophical and emperical investigation.

Ganiel & Hofstein (1982) in their study concluded that practical examination have sever drawbacks if they are used only on special occasions such as in final examination. Furthermore practical examination in which the assessment is based on clearly defined criteria are not very useful, since their outcome will be greately influenced by personal preferences and biases of the particular examiner.

It was found that by using the assessment scheme the assessment of laboratory was greatly improved both in precision and in objectivity. This can also be used during the class throughout session.

Assessment Test

1. Constructs the Experimental set up and other Manipulative Skills (15%).

- Identifies the components of an experimental set up, from a schematic diagram.
- constructs the experimental set up according to a shceme or to instruction.
- Use the correct equipment for each measurement or observation.
- Overcomes simple malfunction of equipment.

2. Observing and Measurement (25%)

- reads the instruments correctly (scale parallex etc).
- performs observations and Measurements correctly.
- records the results (of observation and measurement) clearly.

3. Ordering and Organizing work (10%)

- arranges the equipment on the bench in an orderly manner.
- keeps tidy and orderly records in the note-book.

- Observes safety regulations.
- Completes the prescribed task in the time allotted.
- Concentrates on his work and does not disturb his fellow students.

4. <u>Organizing & processing Data (25%) including graph.</u>

- processes the results of observation correctly.
- Organises tables of measured data efficiently and clearly.
- records results of measurement with correct units and significant digits.
- Constructs graphs correctly (scales, mark data points in coordinate system, best line through data points).
- obtains numerical values from graphs.
- chooses correct formula for calculating unknown variables.
- substitutes data correctly in formula.
- performs computations correctly.

5. <u>Drawing Conclusions and Critical discussion (25%)</u>

- Understands the objectives of an experiment and connections between them and the experimental procedure of its execution.
- decides how many measurements are necessary in order to find relations between variables.

- Identifies the shape of a graph and uses it to find a functional dependence between variables.
- discovers and identifies reasons for illogical results.
- Identifies reasons for improper performance of an experimental system.
- understands the limitations of an experiment and tries to find ways for improvement.
- formulates new assemptions in view of experimental results.

Kyle, Penick & Shymansky (1979) shows that the college level students are performing cook-book like laboratories and that students are not learning the process skills of science but are learning about sƒience. The idea is further reinforced by the amount of time students spent listening. The amount of time students spent transmitting information differed among the five science displines. The nature of activities confronting students in college science laboratories are more directly related to confirming facts and theories and gathèring "correct" scientific data rather than the broader investigation of nature through exploring inquiry, testing and explaninng. This contention is further reinforced by the amount of time which students spent reading and writing in the science laboratories. In nearly one third of the laboratories observed, this combined frequency of reading and writing occured more frequently than what is usually considered the primary objective of science laboratories experimenting. Instructor behaviour is also important. Laboratories are unique in that they can have students doing science as an investigative act instead of merely learning about science. Students should be learning skills necessary for advanced and independent learning in science. Before educators can accomplish the monumental task of knowing the behaviours and interactions which are essential component of the science laboratory must be observed, analyzed and researched. College instructors must be made aware of the educational background of students and the behaviours which may best influence the acquiring of knowledge. College Instructors must also be aware of the behaviours they are exhibiting in their laboratories. When instructors do become aware of the behaviours and interactions which facilitate the transfer of knowledge, then rational and objective statements regarding teacher effectiveness can be made as well as an analysis of which characteristics of instructor class room and laboratory behaviour best facilitate meaningful learning.

Fraser (1980) ~~xx~~ asserted that TOES* can be used for monitoring student progress towards achieving skill aims and assessing entry level skill proficiency. It could also be used for providing information about the average performance of groups of students or the performance of individual students. It is important to use skill tests as well as conventional tests of content achievement. Different students following individual materials in the same class cover different content, tests of content free enquiry skills provide a convenient way of monitoring student progress or aims which are applicable to all students irrespective of the specific content covered. It would be advisable sometimes to administer TOES both as a pre-test and as a post-test in order to obtain information about changes in student performance.

A major advantage that TOES has over ordinary achievement tests is that it yields a separate score for a number of distinct skill aims instead of a simple overall score. This makes it possible to obtain a profile of skill performance for each student or group. An examination of an individuals performance on individual items in skills could enable the diagnosis of deficiences in specific skills. Examination of the average

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TOES* Stands for Test of Enquiry Skills.

Performance of a whole class on individual TOES items could lead to the identification of common skill deficiences which could be overcome through group remedial instruction.

Kyle, Pennick and Shymansky (1980) in their study argue that the p opportunity on the part of students to counteract freely with laboratory instructors was unfortunately non-existent. The fact that instructors initiated intellectual discourse so infrequently could in fact have been an intimidating factor resulting in the low percentage of students initiated questions. It is apparent however that large amounts of time which instructors spend transmitting information is not directly related to student questioning or even to follow up discussion of questions posed initially by the instructor. The obvious question is whether or not colleges and universities have responded in terms of class room and laboratory behaviour in order to accomodate the students of a process oriented education rather than a fact oriented education.

Kozma (1982) in his study asserts that as for main effects, ability plays a major and not surprising role in student laboratory performance and attitudes towards content laboratory performance and attitudes towards content and instructional technique. Prior chemistry achievement and anxiety also influence attitudes towards content. But more important to the teacher designing instruction for the laboratory is the role played by instructional strategies such as stated objectives, examples, requests, responses, and feed back. These strategies provide the necessary conditions for learning and make a significant contribution to students understanding, performance and satisfaction in the laboratory. These benefits occured to students regardless of individual differences in aptitudes, students with high or low ability, high or low anxiety, high or low motivations learned more from this approach.

A final cautionery comment on these results while the full models explain an acceptable amount of variance, the individual effects are rather slight (even though significant). While this may be anticipated from experiments conducted in real class room situations (where many variables remain uncontrolled), it argues for further reinforcement of the experimental treatments examined and continuation of research in this area.

<u>Sex Factor</u>

Selim & Sherigley (1983) in their study pointed out that the Egyptian male and female students had similar scores in science attitudes is probably the unique finding in this study, a finding difficult to explain as one superimposes the results of this study over other gender studies where the male consistently seem to have the edge. One could infer that Egyptian fifth grade females differ culturally from American females the subjects of most gender studies. The open and obvious challenge of males by females observed by the investigator in the Egyptian class room - a competitive spirit contrasting with the social relationship of males and females.

Egyptians - one generation removed suggests that at this point in Egypts social revolution female assertion may be directly affecting science attitude scores. In other words, a new value structure may be developing among Egyptian females and this could be affecting attitudes as predicted by attitude change. Of course similar results in many gender studies at other age levels are necessary before one can generalise this finding across the K-12 spectrum of the Egyptian school population.

Krieger (1982) in his study argues that there appears to be no significant difference between the written test scores mean and the LPT* (Laboratory performance test) score mean when used to measure very specific skills i.e.

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*LPT Stands for Laboratory performance Test).

the ability to take data from graphs and/or instrument scales. Because of the problems with meter drift etc., the paper-pencil analog test may be seen to be superior to the LPT and so is more time and cost effective. The LPT might be better utilised in measuring other aspects of the laboratory experience.

Ross & Maynes (1983) in their study suggests that experimental problem solving skills tests should be used. The merit of these instruments lies in their intellectual utility. There are substantial grounds for arguing that these instruments provides a better means to measure the performance of groups of students in a domain of central importance to science education than competing instruments and that they do so at little cost. The scores from these tests place students on a scale of skill competence that can be immediately translated into instructional action.

The caution is based on the finding that the reliability of the tests is less than optimal and that there are unresolved concerns about validity. These are serious reservations but they should not overshadow the value of the tests to classroom teachers. The final worth of these instruments depends on their value in class room contexts. Only continued experimentation in school environments can provide a definitive answer to the essential questions. Does the information provided by the tests assist teachers in providing a more effective programme to students.

Lynch & Ndyetakura (1983) suggest that much more consideration should be given to the perception of students as a starting point for curricula evaluation. Teachers perception of aims would appear in some respects, to be misguided or misjudged and when viewed against students perceptions indicate some major mismatches. The "producers" claim are not in line with the customers experience. Proponents of neoheurism may be dismayed by some of the student perceptions but it is important that we establish the real nature and orientation of the learning experience and proceed from there rather than cling to idealized notions. What may be very far removed from the reality of the situation. If reorientation are to be made then teachers, teacher educators and curriculum developers should be aware of the true starting point in regard to teacher/pupil perception of events.

Peterson (1977) found that specific instruction in scientific inquiry skills and information was functionally significant value for these students, and that this group benefitted from access to concrete materials and problems along with abstract verbal instructions.

A structural analysis of scientific inquiry behaviour was made using systematic observations of investigative strategies employed by the science inquiry group members. These observations were placed into an overall frame work of inquiry behaviour. The frame work consisted of six transformations or operation rules of scientific investigation. Each transformation was described in five stages of development ranging from lack of operation to its most complete expression.

Suchareekul (1979) found that the most significant implication reported is the IPST* training and IPST curricula were significantly influencing teacher behaviour in the desired direction which suggests the need for intensifying the emphasis upon developing inquiry teaching skills among all teachers. The fact that content validity was strongly supported but predictive validity was not established led the investigator to recommend replication of the study with other population of teachers.

Ilogue (1984) found that there is no consesus yet about the usefulness of laboratory activities in science learning. One reason for this situation is that there are no dependable instruments to measure student's laboratory skills. This study is an attempt to develop and validate an instrument that reflects the various types of learning encountered in the introductory chemistry laboratory.

IPST* Stands for Inquiry Preference Science Test.

Factor analysis was accomplished with options of 7 factors and 3 factors. The three factor results confirmed the significance of the task categories. A majority of the items were significantly related to a factor consisting primarily of items from their task sub-scales. ANOVA* and regression analysis were calculated to study the effects student background variables on performance in CCSLT, Math instruction, sex, high school chemistry type and Ninth grade science caused significant variations in CCSLT performance. The results supported the claim of construct validity.

Laboratory Safety

Ekpo (1981) in his study has concluded that:-

(a) students should be provided with a background of safety instruction on the use of the hazardous equipment, toxic chemicals and body protective equipment to assure personal safety as well as group safety.

b) That students should evaluate their chemistry safety practices regularly and actively work towards reducing laboratory hazards that pose potential dangers,

c) That practising chemistry teachers and administrators should be educated in chemical laboratory safety to assist them in carrying out their safety responsibilities.

ANOVA* stands for Analysis of Variance.

d) That high school administrators should develop and execute in the schools a system of accident reporting and recording.

e) That this study should be replicated to determine the laboratory safety practices and needs in other science areas.

f) That high schools with a course in laboratory safety should maintain liaison with their college bound graduates to evaluate the effectiveness of their training in laboratory safety.

g) That chemistry teachers, school administrators and chemistry students should occasionally assess the present and future laboratory needs as a means of minimizing hazards and ingury.

The module was designed to correct only the weak laboratory practices as revealed by data from the questionaire Activities were included in the following areas (a) Fumehoods and Ventiliation (b) Chemical storage and Waste disposal (c) Safety Equipment and devices (d) hazards of laboratory equipment and chemicals and (e) first aid procedures.

Singh (1982) asserted that (a) there are significant differences in the cumulative health hazards scores of chemicals recommended by the recent editions of chemistry laboratory manuals (b) There are no significant differences in the quality or quantity of health hazards of currently used chemistry laboratory manuals and comparable manuals published prior to 1970 (c) Chemistry teachers in Ohio use extremely toxic chemicals in laboratory activities and have not substituted available non-hazardous chemicals.

Listening Skills

Barufaldi & Swift (1980) asserted that those students who posses the requisite ability are able to benefit from a science programme that is hands on activity centred and enquiry oriented with respect to gains in listening skills.

Shymansky, Kyle, Alport (1983) asserted that (a) Across all curricula students exposed to new science programmes should have the p greatest gain's in the areas of process skill development, attitude to science and achievement (b) Across all curricula overall student performance scores were observed to be less positive in studies where teachers reported having received inservice training in the programme.

Jophus (1982) finds that the analysis of the subjects calculations on the items in the volumeteric analysis instrument revealed eleven main conceptual errors (e.g. indiscriminate assumption of 1:1 mole ratio) made by the subjects. The analysis of manipulatory skills of the subjects revealed that while some skills seemed to be developed other important skills seemed to be lacking. The analysis of the students understanding of concepts involved in acid-base titration revealed that the concepts of pH and indicator behaviour were not well understood. The analysis of the approaches used by the subjects to calculate the concentration of the acid solution revealed the two main approaches. The proportional approach and the formula approach were used by subjects in their solution.

Evaluation of Chemistry Laboratory Skills

A test of chemistry laboratory skills developed by chemistry Associates of Maryland contains 36 test items. (15 manipulative test items and 21 paper pencil test items).

Manipulative test items numbering fifteen relate to grading crystals according to sizes recognition of laboratory equipment etc.

Paper pencil tests numbering 21 relate to reading of volumes, measuring weights, selecting interpreting graphs etc.

All these test items are of alternate or multiple choice. The manipulative test items are the specific tasks to be performed in the laboratory and the answers to be recorded on the basis of observation calculations or conclusions. All these tasks involve the active participation of students under the controlled laboratory conditions.

Some of the tests available with Educational Testing Service to test the science process achievement (though none of them is directly related to achievement in laboratory skills in gernal or chemistry laboratory in particular) are as under:-

1. Interaction science curriculum project student achievement tests: Interaction of Earth and time by Donald Chancy & Hulda Grokman c 1972 Grades 7-8, Rand Mcnally and Company.

2. Interaction Science curriculum project student achievement tasts: Interaction of Man and the bio-sphere by Donald Chaney, Hulda Grobman, (1970-71: Grades 7-8, Rand Mcnally and company.

3. Interaction Science curriculum Project student achievement tests: Interaction of Matter and Energy by Donald Chemey, Hulda Grobman, (1968-69, Grade 9, Rand Mcnally and Company.

4. Methods and Procedures of Science: An Examination by John H.Woodburn (1967 Grades 9-12 John H.Woodburn).

5. School Personnel Research and Evaluation Services speciality Examinations - Chemistry, Physics and General Science: 197-Présent, Grades 16, School personnel Research and Evaluation Services, Educational Testing Service.

6. Wisconsin Inventory of Science Processes by Milton Pella (1967) Grades 12 and above. Scientific Literacy Research Centre.

(VIII) Case Studies of various countries

The National Science Teachers Association of America in a position statement (1982) "Identifying goals of science Education" has stated that students abilities and skills in the laboratory can be assessed through observations made by teacher to determine how well students can manipulate a piece of equipment. Teachers prefer to assess laboratory skills through laboratory performance tests or practicals.

Hearle (1974) has identified and measured high school chemistry laboratory skills in the schools of Maryland (U.S.A.) Some of the major findings of his study were -

1) Students using IAC* curriculum materials were found to have a significantly higher level of achievement in laboratory skills. The levels of achievement in manupulative skills was higher than in the cognitive based skills. The absence of a significant difference in achievement of laboratory skills in relation to sex of the student was examined. Explanations were presented to account for these findings.

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*IAC stands for Interdisciplinary Approach to Chemistry.

The study also revealed a low correlation between the ability to learn subject matter content and the ability to learn either manipulative or cognitive based laboratory skills. Again possible explanations were presented. The study concludes with recommendations for future studies that could provide answers to several of the alternate explanations presented in discussion of the findings of this study. Other recommendations relate to questions raised in the literature.

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