EFFECTS OF METHOD OF INSTRUCTION, ABILITY AND SEX , WITH COVARIATES : PREVIOUS MATHEMATICS LEARNING ; MOTIVATION; HOME SOCIO-ECONOMIC STATUS; AND ATTITUDE; ON MATHEMATICS ACHIEVEMENT OF ZAMBIAN STUDENTS IN TWO SECONDARY SCHOOLS

by

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Doctor of Philosophy in Education

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Date ..18/08/.....1989.

APPROVAL PAGE

This thesis of Makhunga Wintshi Njobe is approved as fulfilling part of the requirements for the award of Doctor of Philosophy in Education degree of the University of Zambia.

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ABSTRACT

The study investigated the main and the interaction effects of method of instruction, ability and sex on grade eight Students' Achievement in Mathematics (SAM) in two Lusaka schools in Zambia. Seven null hypotheses tested the effects on SAM of: method of instruction, ability, sex, interaction between sex and method, interaction between ability and method, interaction between ability and sex, and interaction among ability, sex and method.

The sample (N = 96), was drawn from the 1986 eighth grade intake population (approximately 1000) of one girls' and one boys' secondary school. An experimental and a control class were then constituted in each school by stratified random assignment. The study design consisted in a 2 x 2 x 2 Orthogonal Factorial Experiment incorporating for control covariates: previous mathematics learning; motivation toward learning mathematics; home socio-economic status; and attitude towards mathematics.

Five instruments constructed for the study respectively measured SAM and each of the covariates. The Statistical Package for the Social Sciences (SPSS) computer subprogram 3-way Analysis of Variance (ANOVA) with Covariance was used to analyse the main study data. The computer output included a Multiple Classification Analysis table showing the pattern of effects on SAM of the main factors and the covariates. Additional data analysis further investigated some of the main study findings.

At p=0.05 level, the study found the following effects on SAM significant: ability as measured by the aggregate scores in the Zambia National Grade Seven Composite Selection Examination; method-sex interaction; covariate previous mathematics learning; and covariate motivation towards learning mathematics. The study found the following effects on SAM not significant: main effects of method, sex; two-way interactions between method and ability, ability and sex; three-way interaction among method, sex and ability; covariates home socio-economic status and attitude towards mathematics. SAM regressed more on ability than on either method or sex. However, the strength of the regression appeared influenced by covariates effects.

The study concluded that: SAM was significantly influenced by ability as measured by Zambia's Selection examination; ability was a better predictor of SAM than either method or sex; main effects of method of instruction and of sex were not significant. Probably, the significant method-sex interaction might have influenced the main effects of method and of sex.

The study recommended: further research aimed at improving SAM; streaming of mathematics classes; increased use of heuristic instruction for mathematics; and further studies on how sex discriminatory practices in cultural socialisation, social expectations and availing of opportunity according to sex might be affecting SAM.

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CHAPTER I

STATEMENT OF THE PROBLEM

Variables which might influence students' school achievement are many. Students' Achievement in Mathematics (SAM) might be influenced by method of instruction, ability, practices of socialisation into the culture according to sex, previous mathematics learning experience, attitude towards mathematics, motivation towards learning mathematics, and the home socio-economic status among other factors. Yet successful mathematics learning and teaching is presumed to play a key role towards better understanding in learning the science and technology necessary for national development. Theoretically, there appears to be a need therefore, in Zambia as elsewhere in the developing world, to improve the effectiveness of mathematics teaching, learning and popularity of the subject in schools. Often, developing countries including Zambia, might face serious problems of foreign exchange to import mathematics education, science and technology necessary for national development.

Improved achievements of Zambian students in mathematics, could help improve the students' achievement in science, technical and other mathematics related subjects. More students graduating with mathematics and science from Zambia's secondary schools could then be expected to enter and graduate from institutions of science and technology. This output of highly skilled manpower in science and technology could then become available for developing a locally based and cheaper technology more suited for solving problems of development in Zambia.

The Problem of the Study

In Zambia, the planned education reforms now being implemented, have called for mathematics, science and technology to be given "more importance" in the curriculum.[1] The students are required to master and "show ability to use mathematics concepts and processes" with increased effectiveness.[2] Zambia wants improved performances of her secondary school students in mathematics and science to enable more of the students to enrol in science and technology courses in Zambia's university and colleges.[3] However, the Zambian government has observed a generally poor" performance of Zambia's secondary school students in mathematics and feels concerned about the situation.[4] The School of Engineering at the University of Zambia has found itself being able, since 1969, to graduate only about two percent of the engineers Zambia needs.[5] A University of Zambia study [6] found a high mathematics failure rate among undergraduate students being prepared for secondary school teaching. The study also found that "with few exceptions the Schools of Natural Sciences ... and Education retain students at around the 3rd level of excellence in mathematics in their 2nd and subsequent years".

Research studies related to the development of mathematics cognitive skills among Zambian children, have identified some of the problems experienced by the children as including : mastery and use of number skills (Sharma and Henderson, 1974); use of rudimentary quantitative strategies learnt in mathematics (Kingsley, 1975); handling of spatial relations and geometric shapes (Okonji, 1972); pictorial depth perception of three dimensional problems (Serpell and Deregowski, 1972) among others.

The foregoing studies were conducted on primary school level children. Literature did not appear to show any Zambian studies on factors that might be affecting mathematics achievement at the secondary school level. The question of how the foregoing mathematics learning problems of the primary school children flow onto the secondary level to affect SAM remained unanswered. Therefore, there appeared to be a need to investigate factors that might be affecting SAM in the secondary schools in Zambia. A multivariate study design appeared more appropriate for such an investigation since effects of many other variables were expected to affect SAM.

The main questions of the present study problem therefore sought answers to: Are there any differential effects on the mathematics achievement of Grade Eight Zambian students accountable in terms of the students' sex, ability and method used to instruct the students ? Are there method, ability and sex two-way and/or three-way interaction effects on SAM ? That is, what are the main and interaction effects of method of instruction, ability and sex on SAM among high and among low ability students of either sex when taught by heuristic and when taught by expository method of instruction ? A corollary question to the foregoing on covariates was, what effects do the covariates students' previous mathematics learning, motivation towards learning mathematics, home socio-economic status and attitude toward mathematics have on SAM ?

The questions appeared appropriate in a search for ways of improving SAM in Zambia's schools. Improved quantity and quality of SAM in the schools could contribute more success to the training of creative and productive scientists, technicians and engineers for national development aimed at improving the quality of life of all Zambians.

Purpose of the Study

The purpose of the study was to seek answers to the questions raised under the above stated study problem. Towards this end, seven null hypotheses and alternative hypotheses were formulated to find out what were the main and interaction effects of method, ability and sex on the mathematics achievement of the study sample. That is, the study sought to find out whether or not the mathematics achievement (SAM) of the 1986 Grade Eight students just enrolled - some to the Boys' and others to the Girls' study secondary schools - was differentially affected by :

(i) heuristic versus expository method of instruction;

(ii) high versus low ability of students as measured by the students' aggregate scores on the Zambia National Grade Seven Composite Selection examination;

(iii) sex of student;

(iv) interactions of method versus ability, method versus sex, ability versus sex, ability versus method versus sex.

A corollary found necessary to include to the foregoing purpose, was to control and assess the effects - on SAM and on main factor relations with SAM - of covariates: previous mathematics learning; motivation toward learning mathematics; home socio-economic status; and attitude toward mathematics. Below, follows a framework within which the study was conceived.

Conceptual Framework

To guide the search for answers to questions raised above under the study problem, the following theoretical framework was conceived. The framework incorporated assumptions made on the basis of common sense and findings of other Zambian studies. Excerpts from Piaget's theory of cognitive development and some concepts hypothesised by Hudson (1960) and Witkin (1967) were used to impose a theoretical structure as briefly referred to below.

Incorporated from Piaget's theory (Copeland, 1974) is the conception of how the beginnings of "logico-mathematical knowledge" and mathematical abstraction occur during the child's play experience in the home environment. Piaget expected fuller mathematical abstraction to be manifest by the phase of Formal Operations. Piaget predicted that the phase of Formal Operations should occur from between eleven and fifteen years of age. Among Zambian children however, Nkwanga (1982) found that a Piagetian phase might appear later than in Piaget's Geneva results. The sample subjects of the present study, at the estimate age of 15 years on the average[7], were assumed to have attained Piaget's phase of Formal Operations.

Attainment of the age of Formal Operations however, is not a sufficient condition for the full development of basic logico-mathematical structures, which in Piaget's theory should give rise to logico-mathematical knowledge and mathematical abstraction. Successful development of this knowledge and abstractions also depends on the child's experience gained during playing with toys, games and so on in the home environment. This experience, in Piaget's theory includes (a) physical experience gained from physical actions on objects in the environment. (b) Logical mathematical experience which is gained as an internalisation of cognitive abstraction from the experience in physical actions. Piaget saw the latter as "the beginning of mathematical abstraction" (Copeland, 1974: 32).

Piaget illustrated the foregoing as follows. Physical action might involve arranging and re-arranging marbles into different formations. The child might at the same time be counting these marbles in a mental action. The counting might be done repeatedly in different directions in each formation. The child then finally arrives at an abstraction that the number of marbles remains the same irrespective of the order, formation or direction of counting. This logical mathematical abstraction is then internalised and becomes available for use in related new situations. The latter need not have been preceeded by any physical experience of their own. In a related context, Piaget thought that "interchage of thought" (probably as between mother and child) as well as "cooperation with others" are also important factors in the individual's cognitive development.

The foregoing theoretical assumptions will now be applied to the Zambian situation - on which the present study is focussed - to gain a guiding conceptual perspective for the present study. The kinds of toys, games, parental stimulation and interchage of thought with their children and so on, all appeared relevant and important in the development of cognitive processes as postulated by Piaget in the above exposition. Parental awareness of their children's mental needs for the kind of skills and basic knowledge school mathematics will require appeared crucial in the home preparation of children for school. However studies by Goldberg (1970) and Munro (1968) on Zambian children in suburbs of Lusaka, found that the development of cognitive skills was inadequately attended to by the parents. Appropriate toys, games, pictorial and writing materials for children were often lacking. This was in homes of lower socio-economic status. Munro also found *that the boys appeared more free than girls to engage in* a variety of local outdoor games, and other activities. Differentials of this kind in childrens early experiences, might also show up in sex related differences in school mathematics performances. Social prescriptions of sex roles, expectations and other socialisation practices of this kind in the culture could also be material in this regard.

Also apparently relevant to the child's opportunity for Piaget's physical and mental actions towards the development of logico-mathematicsl structures , are some traditional child rearing practices. In Zambia, as mostly elsewhere in Africa, rearing practices often include the use of a cloth sling to confine the potentially active and curious child to a comfortable lazy state of inaction on the mother's back. Goldberg (1970), in a study of Lusaka infants, thought that the cloth sling served as a baby cot, playpen, buggy and feeder. One possible merit of modern baby cots, playing pens and so on, is the freedom a child enjoys in them to explore and experiment with the appropriately selected, often colourful toys placed in them. One assumption of the present study is that long periods of a child's life spent in a cloth sling could hamper the adequate development of the Piagetian logico-mathematical structures required for good performance in future school mathematics.

The home culture appears to deserve a place in the conceptual framework of the present study. Hudson (1960) hypothesised that culture might be categorised as visual and non-visual. To the extent that traditional Zambian cultures, as others in Africa, appeared to have lacked a precisely developed traditional system of symbols of communication in writing, pictures, numeration and so on, the present study therefore assumed the traditional form of such culture to have been visually less developed. Children growing in a visually less developed cultural atmosphere at home, might experience deprivation of an adequate opportunity to develop some mathematical skills such as those related to number and pictorial depth perception. This could result from limited experience possible with number and picture in a culturally less visual home environment. Serpell and Deregowski (1972) found that Zambian children in a Lusaka suburb experienced problems with pictorial depth perception of three dimensional drawings.

The influence of a visually less developed home cultural experience on a child's development of cognitive skills, might also increase the chances for more of Witkin's (1967) less articulate, less analytic 'Field-dependent' cognitive style stereotypes amongst students. The development of

Field-dependent and Field-independent cognitive styles, in Witkin's view, could also be influenced by the manner parents handle the "child's expression of impulse" as well as by the ecology of the home environment (Witkin, 1967:235). In the Zambian cultural context therefor as elsewhere in Africa, child rearing practices - including the dimension of permissive versus rigid conservative upbringing according to tradition - might be material. A Field-dependent cognitive style might be expected to hamper a student's ability to be articulate and analytic in computing or solving mathematics problems. Children growing in a less permissive cultural setting, might be less used to asking questions but more probably inclined to do as told. If this assuption were valid, children of the kind, could be expected to be more open to rote learning. Thus such children might be happier with expository kind of instruction than with heuristic instruction.

Assuming the validity of the foregoing theoretical postulates (Piaget in Copeland, 1974; Hudson, 1960; and Witkin, 1967) and study observation and assumptions referred to above, the following general hypotheses are now put forward for the present study. The general hypotheses will subsequently be broken down in part into null hypotheses and alternatives more specific for testing in the present study.

General Hypotheses

The main hypotheses of the present study are now given below in general form. A brief statement of the rationale for each is also given.

1. Not withstanding early childhood deprivation of optimum opportunity to develop Piaget's Logico-mathematical structures, an appropriately designed Heuristic Instruction Method (HIM) will enable even the affected children score higher on mathematics achievement tests than control groups taught by an Expository Method of Instruction (EMI). The prediction will hold irrespective of sex and level of ability. The rationale for the hypothesis is that HIM will enable the students correct some of the adverse effects of lost opportunity in early life to explore and experiment with some mathematics concepts on their own to develop Piaget's necessary logico-mathematical structures. HIM by its nature is a method where students explore to discover abstractions on their own.

2. Students taught by HIM will show more positive correlation between attitude and achievement than students taught by EMI. This should be expected since concepts learnt through HIM should become more rooted in an understanding of meanings. The result should be to enable these students to formulate more definite attitudes towards mathematics. EMI on the other hand is too open to chances of rote learning. Rote should leave learner's preferences of like / dislike and beliefs about mathematics (Rosenberg 1967) diffused and more inclined to be random. This situation should be reflected in a weak correlation between attitude and achievement.

3. Students taught by HIM will show motivation levels which are more correlated with SAM than students taught by EMI. This should be expected since HIM by its very nature should stimulate students — by its builtin reinforcement characteristic of discovery — towards extending their horizons of knowledge further compared to students taught by the passive prone EMI.

4. Female students, on the whole, should perfom relatively poorer in mathematics and hold relatively less favourable attitudes toward the subject than male students. This should be expected to hold irrespective of method of instruction used or level of ability. The hypothesised reasons are that:
(i) Male students in Zambia as elsewhere in Africa, probably tend to enjoy more outdoor freedom to explore and experiment with objects in the environment than female students. In this way, male students in early life gain a better chance to experiences which enable them develop more successfully Piaget's logico-

mathematical structures necessary for school mathematics.

(ii) Social attitudes might tend to categorise mathematics for science and technologically related careers as being in the domain of men than women. Correspondingl women become unexpected nor encouraged to think of venturing into this domain. This is correspondingly expected to affect women mathematics performance and attitudes.

4. Students from homes of higher socio-economic status should, on the whole, achieve better in mathematics than students from lower home socio-economic status. The expectation is based on the assumptions that: (i) Students from higher home socio-economic status are more likely to have had educated parents than students from lower home socio-economic status, Such parents should be more aware of their children's menta needs for school. Educated parents therefore would probably help their children to develop at least some of the appropriate logico-mathematical structures through guidance and purchase of appropriately select toys, games and so on. (ii) In early life students from higher socio-economic status homes, more probabl escaped much of the docile life of being confined in a cloth sling. Children from these homes were probably brought up more in modern baby cots, buggies and so o (iii) These children were also more probably brought up in more visual cultural home environment with fair supplies of number picture and other related material providing them with opportunity to develop some of Piaget's logico-mathematical structures necessary fo success in the kind of mathematics taught in school.

Below, aspects of the foregoing general hupotheses were reduced into specific null hypotheses and alternatives for statistical testing. Preference was to retain even the untested in the present thesis for some other future testing towards, perhaps, building a more all embracing hypothesis. Two-tailed tests were used in the present stud to test stated hypotheses so as to be able to either accept or reject them on the basis of relevant predictions (Ryan, 1959)

Specific Hypotheses

The seven null hypotheses (h_o) and their alternatives (h_1) respectively formulated on the questions of the presen study problem are presented below. The same hypotheses will each be tested by two-tailed tests at the p=0.05 level of statistical significance.

h_o One : There is no difference in SAM when students are taught by either a heuristic or an expository method of instruction.

h_1 One : There is a difference in SAM when students are taught by a heuristic method and when taught by an expository method of instruction.

h_o Two : There is no relationship between SAM and student levels of ability.

h_1 Two : There is a relationship between SAM and the students' levels of ability.

h_o Three : There is no relationship between SAM and sex of the student.

h_1 Three : There is a relationship between SAM and the sex of the student.

h_o Four : There is no sex versus method of instruction interaction effect on SAM.

h_1 Four : There is a sex versus method of instruction interaction effect on SAM.

h_o Five : There is no ability versus method of instruction interaction effect on SAM.

h_1 Five : There is an ability versus method of instruction interaction effect on SAM.

h_o Six : There is no ability versus sex interaction effect on SAM.

h_1 Six : There is an ability versus sex interaction effect on SAM.

h_o Seven : There is no ability versus sex versus method of instruction interaction effect on SAM.

h_1 Seven : There is an ability versus sex versus method of instruction interaction effect on SAM.

Consequences of the Hypotheses

The consequences of the hypotheses indicated below, are limited only to the extent of the two-tailed testing at th present study of $p=0.05$ level of statistical significance.

The outcome of testing h_o One, that SAM is not related to method of instruction, could either be an acceptance or a rejection of the hypothesis. If h_o One, that is SAM was not related to method of instruction, were accepted, then the conclusion might be that the two methods of instruction had no difference in effect on SAM. Wallis (19 finding, that empirical evidence did not appear to support consistent set of hypothesis regarding the relative effica of student discovery and teacher dominated instruction, could then be supported. Also in that event, a possibility might exist that other factors were at play. One such fact might be an interaction effect between method of instructi and some other main study factor(s). Further investigatior might then be necessary.

If h_o One were rejected, then either the heuristic metho might be more effective than the expository method or vice versa. If the heuristic method appeared more effective than expositor meth then one suggestion might be that the element of learner activity and involvement inherent in heuristic instructior might account for such observed differential performance.

Learner involvement probably also aroused posit emotional feelings concerning what was being learnt. Feel such as these might enhance motivation toward learning, acq sition of meanings and a more positive attitude toward mathematics materials being taught. Consequently, bette mastering in mathematics learning might be achieved. Lear experience of the kind might more approximate 'meaningful verbal learning' postulated by Ausubel (1968). Whether heuristic or expository method were found more effective, more effective method could then be recommended for mathe matics instruction in Zambia's schools. However, more inv igations might still be necessary on the recommended metho

The result of testing h_o Two that SAM is not related to students' ability, might either be an acceptance or a rej tion of the hypothesis. Accepting h_o Two that students' ability had no significant differential effect on SAM, mi *be at variance with Cohen (1976) finding that ability is "capacity to learn" and achieve well also supported by* Vernon (1971:3). The finding might need further investigati If h_o Two were rejected, then the alternative hypothesis h_1 Two that SAM was related to ability would stand. Then special measures might need to be found to improve SAM for students with less ability. Such measures might include streaming of classes according to ability. Under streaming the less able students could receive specialised attention toward improving their mathematics achievement. The latte attention might include use of special instructional metho and aids. If there is a positive relationship between SAM and ability, mathematics teaching could be intensified for high ability students to raise further the level of science and technology graduates needed for national development aimed at improving the quality of life of Zambians. A rejection of h_o Two could also mean that ability – as measured in the present study by aggregate scores in the Zambia National Grade Seven Composite Selection Examination – might then be a predictor of SAM among Zambia's Junior Secondary school students. A rejection will also mean that either the high ability students achieve more than the lower ability students or vice versa. In the event of the vice versa, further investigations might become imperative.

The testing of h_o Three could result in an acceptance or a rejection. Acceptance of h_o Three that SAM is not related to sex, could lend support to Zambia's policy of offering mathematics on the school curriculum without discrimination on grounds of sex. Consequently then, to that extent, men and women have equal opportunity to train for careers in science and technology. A rejection of h_o Three could mean that either the male students achieve better in mathematics than the female students under equivalent conditions or vice versa. Stereotype careers according to sex might then become a more accepted phenomenon. Mathematics, science and technology might then be seen as being more in the domain of the sex doing better in mathematics. To that extent, the source of expert manpower for Zambia's development could become limited accordingly. In either case of acceptance or rejection of h_o Three, the implications could be important for curriculum development, methods of instruction, education policy and so on.

The result of testing h_o Four, that method of instruction does not interact with sex to affect SAM, could either be an acceptance or a rejection. Accepting h_o Four might not exclude the existence of main effects of method and of sex on SAM. If h_o Four is accepted, then the effects of instruction method on either sex would be in the same direction. That is, the effect of heuristic method in relation to the effect of expository method on SAM scores would be similar for males as for female students. Thus, if heuristic yielded higher scores for male students, so would it yield higher scores for female students and vice versa. If h_o Four is rejected, the interaction effect on SAM due to method of instruction and sex must then be positive for one sex and negative for the other sex. Thus either the male students responded better to heuristic than expository while the female students respond better to expository than heuristic or vice versa. Rejection might be indicative of a need for further studies to determine the more exact nature of the interaction effect. The latter could then help in the choice of a more appropriate mathematics method of instruction for either sex.

The result of testing h_o Five that there is no ability versus method of instruction interaction effect on SAM could either be an acceptance or a rejection. An acceptance could still mean that one or the other or both of the main effects of method and of ability exist. An acceptance would also mean that the effect of method of instruction on SAM has the same direction for both high and for low ability level groups. That is, if the heuristic method raises the achievement of high ability students compared to the expository method, then the heuristic method should similarly raise the achievement of lower ability students and vice versa.

Rejection of h_o Five, that is, if there was no method versus ability interaction effect found on SAM, there might still be main effects of one or both of the factors of ability and method. Rejection might also mean that the interaction effect of method of instruction might be positive for one ability level group and negative for the other ability level group or vice versa. If the result is a rejection and the high ability responded more satisfactorily to the heuristic than to the expository method or vice versa, then the low ability might respond less satisfactorily to the heuristic than to the expository method or vice versa. Either outcome would be important to consider in choosing an appropriate method of instruction for either high or for low ability students. But in the event of a rejection further investigation might be necessary.

The result of testing h_o Six that there is no ability versus sex interaction effect on SAM, could either be an acceptance or a rejection. In either event, there might still be main effects on SAM of one or both of the factors of ability and sex. If h_o Six is accepted, then it could mean that the effect on SAM of ability on either sex is in the same direction. That is, if the male students of high ability scored better than male students of low ability under equivalent conditions, then female students of high ability should also score better than female students of low ability under equivalent conditions or vice versa.

Rejection of h_o Six means accepting that there is an ability versus sex interaction effect on SAM. However, there might still be main effects on SAM due to one or the other or both factors of ability and sex. The interaction effect of sex and ability might be such that the interaction is positive for one ability level group and negative for the other ability group, or vice versa. That is, if male students of high ability scored more than male students of low ability under equivalent conditions, then female students of high ability might score less than female students of low ability under the same equivalent conditions or vice versa. The latter might need further investigation to determine the more exact nature of the interaction effect and possible ways of correcting the situation.

Testing h_o Seven might result in an acceptance or rejection. If acceptance, then it could mean that the method of instruction, sex and ability had no interaction effects on SAM. That is, the three-way interaction effect on SAM due to method, ability and sex could be equally positive or equally negative. Inspite of an acceptance or a rejection of h_o Seven, there might still be main effects of each of the factors on SAM. If testing of h_o Seven resulted in a rejection, that is acceptance that there is an ability versus sex versus method of instruction interaction effect on SAM, various possibilities might then arise. Situations where the interaction is most effective might require further study.

Assumptions of the Study

Assumptions which further guided the study include :

(i) Attitude, motivation and home socio-economic status can be measured by scoring responses of subjects to statements in a questionnaire by use of a rating scale.

(ii) Such measures can be validly made by scales along a linear continuum of favourable to unfavourable or high to low on the principle of a Likert type scale.

(iii) Measures resulting from such scales can be treated as interval data.

(iv) Students'achievement in mathematics might also be influenced by other variables - not included in the present study design.

(v) Such other variables might include those pertaining to home, community, school, learner, teacher and subject matter characteristics.

(vi) There might be main and interaction effects among the study and the other variables influencing SAM.

(vii) Covariates were assumed to have a linear relationship with SAM (Nie et al., 1975:9)

Significance and Importance of the Study

Zambia believes that for her development to improve the quality of life of Zambian people, science and technology must be the "single most important" in the 1985 to 1995 decade.[9] The importance of mathematics as the key to science and technology therefore, cannot be over emphasised. McParland, after a review of a study by a Commonwealth group on technology in Africa, concluded that "school education should be aimed at developing the skills most in need: science and mathematics".[10]

Understandably therefore, the Party and its Government in Zambia, are investing a large portion of the nations resources in the teaching of mathematics and science. The hope is that this investment could yield results useful to "meaningful development". In doing so, Zambia states that some of the perennial problems of development could be effectively solved. Problems of the kind are said to include those related to adequate food production, development of the mining industry and water supplies, health, housing and others. Solutions, in Zambia's belief, could come by if Zambia produced enough of Zambia's own scientists of high quality and creative ability, to be able to adapt existing science and technology to solving development problems experienced under Zambian conditions.[11] Successful teaching of mathematics therefore might provide Zambia with another powerful instrument for raising, in the ultimate, the quality of life of all Zambian people through development.

On the other hand, the Zambian Government has observed that students' achievement in mathematics at the secondary school level is "generally poor".[12] The poor mastery of some mathematics concepts by some of these students, has also been said to be affecting the students' performances in the natural sciences.[13] One Zambian study "clearly established a correlation" between achievement in mathematics and achievement in other natural sciences subjects among first year students at the University of Zambia.[14]

Achievement of students in mathematics could be influenced by methods of instruction, ability, sex, previous mathematics learning, motivation toward learning mathematics, home socio-economic status, attitude towards mathematics and pre-school child preparation for school among other factors. However, literature showed a scarcity of Zambian studies on the foregoing and related variables concerning mathematics. Yet from Zambian schools must come Zambia's future mathematicians, scientists and engineers. Failure to give adequate attention to studies on students' mathematics learning problems could be a serious omission. The present study is designed to contribute towards closing this gap. The outcome of the study, might be useful towards finding ways of improving SAM in Zambia.

Improved performances of Zambian students in mathematics could help the students master sciences as well. Students' successes in mathematics could motivate students toward careers in science and technology for the development of Zambia and the improvement of the quality of life of Zambians. The outcome of the present study might also stimulate more studies similar to this one on Zambian students' learning problems

Findings accumulated from such studies could be valuable source material for teacher trainers, teachers, text book writers, curriculum policy makers and curriculum developers. Standards of education in Zambia might thus be improved to the good of all Zambians.

Limitations of the Study

The present study was limited to the relationships among the variables investigated. Except for the Factorial Experiment component of the study design, the study was not confined to a discovery of causal relationships only. Variables not covered in the study such as students' stages of mental development as suggested by Piaget (1972), self concept and anxiety about mathematics limited the study conclusions.

Probably better still, the period of instruction of the study could have been longer than the five weeks taken. A longer period might have enabled the students to become more acclimatised to the respective instruction methods used. The resulting sample subgroups'SAM mean scores might then have become confidently acceptable as reflection of the effects of instruction methods used. However, fixed schedules of the schools for the term and other factors beyond control tended to limit the possible instruction period.

Perhaps the study could have been also stronger if the subjects could have been sampled from Zambia's entire intake population of the 1986 Grade Eight students. The high versus low ability gap between the study sample subgroups could then have been made wider. The quality of study results might have then been better. Limitations in this regard, as in the number of variables that could be included was largely due to constraints on time and resources available.

Definition of Terms

Operational definitions formulated for some of the terms used in the study are given below.

Ability The aggregate scores of the students in the six equally weighted papers taken at the 1985 Zambia National Grade Seven Composite Selection Examination were used as measures of ability. National selection of Zambian students into the 1986 Grade Eight classes was done on the basis of these aggregate scores. The scores represented composite scores of the students in tests of achievement and intellectual ability. The tests covered content in English, mathematics, science, social science, verbal and non-verbal reasoning ability. Thus the aggregate scores used as measures of ability in the present study did not strictly represent Intelligence Quotient values.

Achievement Students' Achievement in Mathematics (SAM), for the purpose of the study, was measured by the students' scores on a standardised mathematics posttest designed to measure cognitive learning outcome resulting from the study instruction methods.

Attitude The operational definition of attitude for the study was based on the conceptual definition proposed by Katz (Dawes, 1972 : 16). Attitude toward mathematics therefore was taken as the student's predisposition - as judged from scale responses - to evaluate mathematics along a continuum of very favourable to very unfavourable according to some core feeling of liking or disliking mathematics on the basis of belief elements concerning mathematics. Operationally, a student's response to a questionnaire statement was scored on a five point Likert type[15] continuum from very favourable (supportive) opinion to mathematics (5 points) to very unfavourable (non-supportive) opinion to mathematics (one point). The total of points scored by each student on all the questionnaire attitude statements was taken as the student's attitude score toward mathematics.

Motivation Conceptually, motivation was viewed as an attracting force toward some human actions inspired by mental representations of desired goals. Operationally following upon this conceptual view, a student's motivation was taken as the level of the student's desire to learn mathematics. The intensity of this desire, was measured by the student's total score on all statements of a motivation scale specially constructed in the study for the purpose. A student's response to each statement was scored on a five point Likert type continuum of preference supportive of being very desirous of learning mathematics (five points) to being very undesirous of learning mathematics (one point). Thus the total points scored by each students on all the questionnaire motivation statements was taken as the student's motivation score toward learning mathematics.

<u>Heuristic Method of Instruction</u> Heuristic Instruction Method (HIM) in the present study, was one in which the students were expected to interact with the subject matter of instruction. Attempts were made to motivate and allow students chance to discover on their own under the teacher's guidance meanings, relationships, methods of solution, generalisations and conclusions concerning lesson material presented. The students in each case were initially presented with a brief background with a minimum of details necessary and then asked to find answers and solutions as guided by the teacher's questions.

<u>Expository Method of Instruction</u> Expository Method of Instruction (EMI) was one in which learning materials were presented to the students in detail. The teacher then posed questions and problems based on the detailed presentation and then promptly proceeded with the task of answering or solving them for the students without giving the students much chance to do so. The students were expected to passively listen and 'learn' the subject matter taught.

<u>Socio-Economic Status of the Student's Home</u> The Socio-Economic Status (SES) of a student's home was considered as high or low according to the aggregate scored by the student on an SES instrument specially constructed in the study for the purpose. The instrument scored a student's

home SES on the basis of the student's responses to statements formulated on the indicators: educational qualification, occupation and rank in the job of each of the parents or a guardian; educational qualifications, occupation and ranks in the jobs of the <u>most</u> successful brother and of the <u>most</u> successful sister; occupation of the husband of the most successful sister - for extended family considerations; parental provision of mathematics related playing environment during the sample student's pre-school ; and current parental help, when in difficulty, with mathematics homework.

<u>Organisation of the Study</u>

The study report was organised in such a way that Chapter I presented the statement of the problem. The statement comprised a theoretical framework, the problem, purpose of the study, a conceptual framework, general and specific hypotheses, consequences of the hypotheses, assumptions, significance and importance of the study, limitations and definitions.

Chapter II reviewed literature related to the : development of mathematics teaching in Zambia since independence; dependent and independent variables and covariates of the study; and other studies thought petinent to the present investigation. Foreign literature was reviewed only where Zambian literature was in short supply. The methods followed in the study were outlined in Chapter III. These included descriptions of population, study sample, sampling procedure, instruments, data collection, control of variables and data analysis. In Chapter IV, the results were presented and discussed. Finally, Chapter V presented the summary, conclusions and recommendations of the study. The bibliography and appendices were included at the end of Chapter V.

Notes

1. Republic of Zambia, Ministry of Education Educational Reform. Proposals and Recommendations. (Lusaka : Government Printer, 1977:106).

2. Republic of Zambia, Educational Reform. 1977:17 .

3. Sunday Times of Zambia. 22 July 1984. Report of an interview with the Minister of Higher Education, Zambia.

4. ibid.

5. ibid. Percentage calculated from figure reportedly given by the Dean of UNZA School of Engineering Dr. F. Yamba in the same news report.

6. Banage, W., Bartholomeusz, E.F., Henkel, R., Lungu, E. M., and Yandila, C.D. "Draft Report of a study of students' performances in mathematics in relation to the students' performances in other courses offered at the University of Zambia". Copy in the Special Collections Section University of Zambia Library, Lusaka.

7. Estimate made on the basis that Grade One admission is open to seven year old children. The children should then turn 15 years of age when in Grade Eight.

8. R. Likert, "The Method of Constructing an Attitude Scale" in M. Fishbein (Ed.), Readings in Attitude Theory and Measurement. (New York : John Wiley, 1967:325-331)

9. United National Independence Party, The National Policies for the Decade 1985-1995. Aims and objectives of the Party Programme. Issued by Office of the Secretary General, Freedom House (Lusaka: Government Printer, 1984).

10. Sunday Times of Zambia, 5 January 1986. Germini news item.

11. Times of Zambia 16 July 1984. Report on the Opening Address to a Regional Junior Engineers and Technicians (JETS) Fair by Member of the Central Committee of UNIP for the Central Province of Zambia.

12. Sunday Times of Zambia 22 July 1984. Report of an interview with the Minister of Higher Education Zambia.

13. View expressed by Mr W.M. Kaiba, Inspector of Science Ministry of Education, Lusaka, when interviewed by the researcher on 17 July 1984, at the Ministry of Education Headquarters.

14. From a study by A. Ngwengwe quoted in the study of note 6 above.

15. R. Likert as in note 8 above.

16. The idea of including the immediate members of the extended family in evaluating students' home socio-economic status in an African situation originated in a discussion the researcher had with Dr P.P.W. Achola of the Educational Research Bureau, UNZA.

CHAPTER II

REVIEW OF SELECTED LITERATURE

Related literature was reviewed within the theoretical framework of the study. The review was summarised as below under various subheadings. The subheadings covered the review of literature related to : the dependent and the independent variables of the present study; covariates controlled in the study; problems of English language medium of instruction and teacher training in Zambia's primary schools; and studies related to the effects, on school performance, associated with cultural practices.

Development of Mathematics Teaching in Zambia

At Zambia's independence in 1964, mathematics was at least not a popular subject among external candidates for the Overseas General Certificate of Education Ordinary and Advance levels.[1] The reasons, probably varied from unfavourable attitudes towards mathematics acquired from society, such as beliefs that the subject was difficult, to the students' own experiences with the abstract nature of some mathematics concepts taught in school. Childhood experiences of the students in the home and community might also have failed to help them develop the kinds of basic cognitive structures school mathematics was to require later. Perhaps to the present day, mathematics has not yet become that much more popular except that it is a compulsory subject in the school curriculum. In 1964, of the 890 bursary awards for diploma, university and other specialised courses offered in Zambia's institutions and abroad, only one student was recorded as specialising in mathematics.[2]

Thereupon, the Ministry of Education of the newly born Republic of Zambia, moved to change the situation as the following measures indicate. The 1964 Annual Report of the Ministry of Education, noted that measures were taken to prepare teachers to "teach children in a logical manner the fundamental ideas and skills needed in a modern technological society". Towards this end, modern mathematics curriculum materials - such as texts on "Basic Concept Mathematics" emanating from the "Entebbe Mathematics Workshop" of 1963 - were adopted for teacher training programmes. The Annual Report further noted that a Lusaka Institute of Mathematics Teachers was founded in the same Independence year. Heads of seventeen primary schools and some of their assistant teachers were members of the Institute. The institute offered inservice training based on a self-help philosophy in teacher education. Courses such as "Teaching the Meaning of Mathematics" and "Mathematics in the Total School Programme" which included field tours were mounted.

In the same year 1964, ten experimental classes involving 400 pupils in "Entebbe Mathematics" programmes for Grade One were also set up. A Mathematics Newsletter covering developments in mathematics education in Zambia as well as a bulletin on problems of teaching and learning mathematics were also planned to keep mathematics teachers up to date with "modern trends in school mathematics".[3]

Programmes of this kind appeared to have continued since. The objective was to promote effective teaching and learning of mathematics. Mathematics was also made a compulsory subject in the primary and secondary school curricula. Consequently, the Annual Report of the Ministry of Education for 1980 showed that mathematics had the largest number of scripts for marking in the Cambridge Ordinary Level School Certificate examination when compared to scripts of entries in any of the other subjects of the examination. However since mathematics was compulsory in the curriculum, the dominance of mathematics entries for the Ordinary Level examination did not mean that mathematics had become more popular nor that the students were doing well in the subject.

Waddimba (1982) studied a Zambian primary school mathematics teachers' inservice course held in 1980. The study found the number of participants, the duration of the course and the course programme inadequate for the magnitude of needs Zambia had for upgrading primary school mathematics teachers. Waddimba also noted that the mathematics course for Zambia's primary schools introduced in 1971 did not appear by 1979 to have received adequate follow up studies to help develop the course.

One University of Zambia study[4] investigated the mathematics performance of students in the various schools of the university. The study found a "3rd level of excellence in mathematics" among students including (B.A. with Education and B.Sc with Education) students being prepared in the School of Education to teach science and mathematics in Zambia's secondary schools. Yet the same study noted that another earlier study by Ngwengwe in the School of Natural Sciences had "clearly established a correlation between" University of Zambia students' performances in mathematics and in the natural sciences. If undergraduates being prepared to teach mathematics and science in Zambia's secondary schools, had serious problems with the mastery of mathematics as might be suggested from the above, a serious multiplier effect could develop - if not intercepted - a tradition of poor performances in mathematics and science among Zambian students would result.

The findings by Waddimba (1982) and the University studies referred to above suggest an urgent need for more to be done to improve the mathematics teaching and learning among Zambian students. Intensified research needs to investigate and provide insights on the mathematics learning problems of Zambian students. Ways of helping the students overcome the problems could then be devised. The mathematics learning problem showing at the university level in Zambia, might well have origins at the primary and secondary school levels of mathematics teaching and learning.

The present study was designed to investigate factors that might affect the mathematics achievement of Grade

Eight students in two Zambian secondary schools in Lusaka. The design enabled a study of the effects of method of instruction, ability and sex on the mathematics achievement of the students.

Students' Achievement

Students' achievement in school subjects might be influenced by : stage of mental development (Piaget, 1972; Gagne, 1965; Bruner, 1964); childhood experience in the home cultural environment (Witkin, 1967; Berry, 1966; Dawson, 1967); childhood experience gained from physical and mental actions during play in the home environment (Piaget in Copeland,1974); method of instruction (Ausubel, 1968); ability (Cohen, 1976); attitude and sex (Clemente, 1982); motivation (Mc Clelland, 1961; Ausubel, 1968; Klausmeier and Goodwin, 1966); self-concept (Roth, 1959; Combs, 1965; Cohen, 1976); anxiety (Banghart, 1959; Ferguson, 1982); and other factors. Review of literature on some of these factors and related concepts, under corresponding headings followed the present review of students' achievement.

Levels of students' achievement are generally used as a measure of the effectiveness of learning. Effective learning, and hence students' achievement, might be hampered by a variety of factors. Brigge and Hunt (1962: 376) described efficiency of learning as "establishing situations" for maximum changes of insight. The latter is probably another important criterion of successful learning expected to manifest in high achievement levels.

Factors hampering learning might include learner, teacher, home, community, school and subject matter related variables amongst others. Maslow (1954) observed that pathological conditions such as boredom (as is possible from a poor lesson presentation), depression and deterioration of intellectual life were produced in intelligent people when their environment and occupational tasks appeared to them unintelligent. Ausubel (1968) insisted that learning materials must be made meaningful to be effectively learnt. School curricula and unintelligently presented learning school programmes and materials, deficient in conveyed meanings, might consequently hamper students' achievement.

Husèn (1967) reported on a study of SAM in some of the developed western countries. The study found that achievement scores tended to be higher at the junior levels of secondary school when "discovery approach" was used instead of "rote methods". Probably therefore learners become more drawn into thought about meanings of concepts being taught in a heuristic lesson than in an expository lesson.

Rote learning is also a significant factor which might hamper retention, recall and transfer of learning results to new situations. Again the expository more than the heuristic method of instruction could be more open to rote. Klausmeier and Goodwin (1966:487), reported that one study found "more than seventy percent" of what is learnt by rote forgotten by a learner by the end of the first day. Sigmund Freud (Strachey, 1962:47-50) put the view that we forget because we want to forget. In this view, ego threatening experience which might probably include compulsory learning of what we fail to understand, thereby threatening to prove us stupid, might soon be suppressed and forgotten. Hopefully, the learning of some materials of a compulsory school does not often induce an unconscious operation of a tendency to suppress and forget. In Zambia mathematics is compulsory in the primary and secondary school curricula. A tendency to suppress and forget might then affect Zambian students' achievement in mathematics.

Similarly, students' motivation to learn might be reduced if the subject materials taught do not appear to the learner to be of any practical value. Mathematics learning materials have also been described as often not clearly showing much practical value to learners.[5] Servais (1970:203) described mathematics as an abstract subject. In Zambia, Nkwanga (1983) found that "mathematical understanding" and "competence" appeared to be lacking in the early primary school (Nkwanga, 1983:49).

In another context of factors that might affect students' achievement in mathematics, Bain (1982) investigated the relationship between low achievement in reading and performance in arithmetic skills among sixth grade pupils in the United States of America. The low achieving readers were found generally to show significantly low arithmetic skills' mastery than high achievers in reading. The language medium of instruction might have been a factor influencing the result. Pressumably English was a first language for Bain's subjects. In Zambia English is a second language but officially prescribed as the medium of instruction at the primary and secondary levels of school. Thus mathematics is also taught through the medium of English in Zambian schools. Consequently therefore, the effects of language found by Bain might be more serious among Zambian students learning mathematics through the medium of English.

Ausubel (1968:521-523) described language as "a necessary condition for ... acquisition" of complex concepts. Ausubel concluded that without "language the development and transmission of shared meanings ... would be impossible". Interaction between persons in this view, is also dependent on language communication. Thus mastery of the language used as medium of instruction in the classroom is important for both the teacher and the learner in facilitating a sharing of meanings. Where meanings are successfully shared achievement should improve.

The learner also needs to be ready for the kind of learning envisaged. One useful criterion of readiness could be the stage attained in the hierachy of phases of mental development postulated by Piaget (1972). In Piaget's theory in general, developmental tasks, including learning, appropriate for one phase must have been reasonably mastered before the tasks of the next phase can be successfully accomplished.

Computation and Problem Solving

In a study of mathematics variables related to computational estimation, Rubenstein (1982) found that some United States of America (USA) students experienced division computations as hardest followed by multiplication, subtraction and addition, in that order. The students also found decimal number computations to be harder than those of whole numbers. Kasanda (1985) also studied computational problems in mathematics among eigth grade students in Winscosin USA. In one finding, Kasanda noted that the students appeared to make "about twice as many errors" in the division than in the multiplication of decimal fractions. Kasanda attributed the cause of most of the errors to deficient previous learning of decimal fractions.

Another study (Garafalo, 1982) on students' arithmetic performance (USA), found a computational versus problem solving dichotomy. The dichotomy also showed itself in (a) low correlation between computation and problem solving test scores. (b) In the tests, computation and problem solving were loaded on different factors. In that study however, it was acknowledged that the dichotomy could not be unequivocal since "several studies" were said to have shown an overlap between the two. It was also recognised that aspects of arithmetic could load together for a variety of reasons such as relate to content, format and other underlying factors.

Computations appear to be more skill oriented. Basic mathematical skill operations are mastered through practice and then applied to problem solving situations. Concepts involved in the problems appear to guide the choice of computational skills that are more appropriate. Novak (1970) asserted that modern learning theory indicates that concept learning should be given more focus of attention. The recommended instructional sequence in this view is one of observation, application of known concepts to what is observed, intepretation, inter-relation to larger concepts and then solution of the problem - the latter pressumably also through the application of computational skills already acquired. Apparently therefore, a link exists among computation and concept learning and the problem solving as an objective.

Duncan (1959:425) thought that problem solving was a "fairly high" process on the dimension of discovery. After a review of related literature, Duncan observed that problem solving appeared to refer to a diverse class of performances. Problem solving in this class differed only in degree from other classes of learning and performance. The difference might be in the extent to which the location and integration of previous learning responses is demanded. Mouly (1968) described problem solving as commencing with a re-organisation of experience related to the problem. However, a problem solver needs to see the problem to be *existing to be able to respond fruitfully* to it. *Thus some appreciation of the problem background knowledge to concepts* involved and familiarity with relevant problem solving strategies are some of the pre-requisite for problem solving.

In the view of Duncan (1959), performance in problem solving varies according to relationships involved among the elements of the problem, level of problem difficulty, aids given toward solution, certain characteristics of the problem solver such as "sex, age and reasoning ability". One might add that the problem solver also needs to fully understand the meanings of the contents of the problem.

The present study design controlled as one of the covariates previous mathematics learning. The measure was an attempt to take into account, among other variables, deficiences in previous mathematics learning such as those suggested by Kasanda (1985) referred to earlier above. Heuristic method of instruction in the present study, was designed to give less aids toward solving problems. Expository method of instruction on the other hand, attempted to give all possible aids necessary.

Instruction

Biggs (Howson, 1973) observed that mathematics was generally an abstract subject. Servais (1970:203) described mathematics as a "science of abstraction". In Biggs' view the teaching of mathematics therefore needs to be in forms that progressively become more abstract. The forms suggested by Biggs include picture graphs, word tables leading onto algebra relations.

Willis (1961) noted from a review of literature, that empirical evidence did not appear to support a consistent set of hypotheses regarding the relative efficacy of student discovery and teacher dominated instruction methods. Apparently therefore, the choice of either method of instruction should be determined by prevailing circumstances in a given situation. Philip (1973) concluded that there was enough evidence to suggest that discovery method of instruction should be increasingly used in teaching mathematics in non-western societies of the developing world, which Zambia is.

Dörner (1978) argued that the school to-day, being consistently required to update what it teaches so as to meet new demands, should generally teach problem solving skills. The skills could then enable the students handle new forms of tasks and problems in post school situations. Dörner thought a more acceptable modern model of cognitive structure consisted of : an epistemic structure serving as a semantic network store of what has been learnt; a centre for heuristic strategies which come into action when the epistemic structure fails to provide guidance to behavior, in the face of a novel problem. The components of the heuristic structure, in the view, include comparing, abstracting, analysing, ordering and so on.

Perhaps Dörner's components of the heuristic structure have common elements with Piaget's (Copeland, 1974) logico-mathematical structures such as classificatory, abstracting and others. It might also be suggested that expository instruction probably receptively feeds content more into the epistemic structure. A good heuristic method of instruction on the other hand, should be better able to develop actively the contents of both the epistemic structure and the heuristic strategies centre.

Dörner further suggested that the cognitive structure then, went into action in the face of a task or problem. Tasks in this view, mainly demanded reproductive thinking which utilised existing learnt programmes. Problems on the other hand, were seen by Dörner as challenges which demand productive thinking in which something new must be created. Perhaps heuristic mathematics instruction, more than expository instruction might develop in learners the kind of productive thinking referred to by Dörner. Husén et al. (1967 :298,Volume II) in a study of mathematics achievement in developed western countries, found discovery approach compared to "rote methods" to yield better mathematics achievement at the lower secondary school level.

The structure of the mathematics subject area selected for the present study consisted of introductory materials to the Algebra of Sets and to Euclidean Geometry of Solid Shapes. The rationale for the choice is discussed under Chapter III below. Appendix VI shows the lesson plans which guided the study instruction. All study instruction was done by the researcher in person. Highlights of some of the researcher's experience during lessons are referred to in Chapter IV-discussions.

The present study, investigated the relative efficacy of heuristic and expository methods of instruction. The Factorial design of the study Educational Experiment, also enabled an investigation of the main effects, two-way and three-way interaction effects of method of instruction, ability and sex factors on students' achievement in mathematics.

Ability

Psychologists differ on the nature and meaning of intelligence. Vernon(1971:3) found that intelligence has been variously defined in terms which include:

> "collection of faculties ... ability to profit from experience ... capacity for abstract thinking ... capacity to learn ... adjustment to the environment"

amongst other definitions. However, these varying definitions do not appear to conflict with the school concept of intelligence as being general ability to learn and achieve well.

Murphy (1935:382) noted that some experimental evidence supported intelligence as learning ability. Terman quoted by Spearman (1970:22) also noted that man is intelligent to the extent that he is able to think abstractly. Abstract thinking in mathematics includes ability to form concepts, master computation processes and solve problems.

Spearman pioneered the use of factor analysis to determine the nature of intelligence. The result was a 'Two Factor' theory that Spearman put forward. The theory postulated that intellectual activity had a general factor 'g' of common ability (Spearman, 1970). There were in addition to the 'g' factor, according to Spearman, 's' factors each of which related to particular intellectual activities. Consequently, in each cognitive activity there was a 'g' and an 's' factor(s). Thurstone (1938), in a move away from the 'g' factor theory, put forward a "Group Factor" theory. Thurstone held that there are independent primary mental abilities which manifest themselves in a factor analysis only as group factors. These were found in the tests of Thurstone's study to include space, number, verbal comprehension, word fluency, rote memory, induction and deduction. Some of these factors received confirmation in subsequent factorial studies (Vernon, 1950 : 20-24). It is however still difficult to conclude from literature that the Group Factor Theory superceded the 'g' factor theory. Recognition of the possibilities of both theories suffices for the purpose of the present study of giving perspective to arithmetical-mathematical ability.

Vernon (1950:41-43) came to the view that most factorial studies did not show much differentiation in group factors relating to mathematics. One conclusion Vernon drew was that there must probably be very few pupils with "special flairs" or special 's' abilities in special study areas of mathematics such as algebra, geometry and others. What might be suspect to the contrary, Vernon thought, might perhaps be accounted for in terms of the ways these different sections of mathematics are taught. If the latter view were valid, then the student's mathematics achievement measured in one section of mathematics material, might be taken as fairly representative of the student's mathematics achievement capability in general.

Vernon (1950:39-40) further noted that classification of mathematics attainment readily tended to show linguistic and mathematical-scientific ability components. Vernon cautioned however that there was a "good deal" of overlap between verbal and numerical abilities. Though tests of mechanical arithmetic and mathematics given army recruits showed different 'g' factor saturations. Vernon (1950:41) observed that these tests had high correlations between themselves thereby making it difficult to deny the existence of a broad arithmetic-mathematics group factor. Consequently, Vernon expressed doubt that Arithmetic, Algebra and Geometry yielded separate factors even though Vernon noted that this had been suggested elsewhere.

Differences exist between individual learners. A learner might also show differences in performance from one school subject to another. Nunnally (1964) illustrated this phenomenon by stating that a learner's bad performance in one field does not predict similar performance in other fields. Individual differences might be accounted for in terms which include: inherited capacity for intelligent behaviour; amount of knowledge and experience already acquired; and the learner's total personality circumstances. Knowledge, experience and personality are also influenced by both learning and the environment. Guildford (1954) used a model to show intelligence as composed of specific factors. Spearman (1970) and Thurstone (1938) from factor analysis studies lent support to the multiple factor view of intelligence. Learners' individual differences therefore probably also have a basis in the multiple factor view of intellectual abilities.

Willis (1961) from literature review, found support for the view that teaching methods relate or interact with students' intellectual ability. Novak (1958) compared a conventional and a project method of teaching a botany course to college students. The study also found an interaction effect between ability and method of instruction.

The present study used introductory mathematics materials to the Algebra of Sets and to Euclidean Geometry of Solid Shapes to evaluate mathematics achievement of the study sample students. The Factorial Experiment design of the present study also enabled two-way and three-way interaction effects of method of instruction, ability and sex on students' achievement in mathematics to be studied.

Sex and Achievement

Ausubel (1968:241-243) reviewed literature related to intellectual ability and sex differences. Ausubel noted that most individual tests of general intelligence were constructed to eliminate differences attributable to sex.

However, the review found that boys and girls differed in opposite directions when tests are weighted on vocabulary. verbal fluency, memory, spatial and numerical abilities. Male students, in Ausubel's literature review, were found to be "indisputably" showing a higher incidence of intellectual eminence. However, Ausubel thought that differential conditions related to cultural expectations, motivation and opportunity could be material in the observation.

Klausmeier and Goodwin (1966) observed that interest in arithmetic and mathematics drops off generally in girls with age toward high school. Boys performance on the other hand, was found to **drop** in language and art during the corresponding ages while there were rises in the sciences. It might be of interest to determine whether or not socialisation practices, expectations of society, manifest in availing of opportunity according to sex, have any influence on student's achievement in mathematics.

The Klausmeier and Goodwin study referred to above, also found girls to be more affected by day dreaming during adolescence in their learning than boys. Vernon (1950:67), in a brief review of studies on spatial factors in school subjects, commented that "one point on which all workers agree is that girls ... are poorer than boys" in spatial *(k) tests.*

In a more recently reported study of sex differences andmathematics achievement, Meece et al. (1982) found "consistent evidence" for sex related differences in mathematics achievement. The differences were specifically found more apparent in tests of mathematical computation and spatial skills at the eleventh and twelfth grades in the United States of America. However, no firm conclusion could be made on biological factors being largely responsible. Instead, socialisers were found to be treating boys and girls differently in a variety of ways. This factor appeared material in observed differences in achievement linked with sex. Other influencial factors found appeared to include : social expectations according to sex roles; self concept of ability; viewing mathematics and mathematics related occupations as being in the domain of men; social beliefs and value systems.

In Africa, Abiri (1966) in a study of attitudes of Nigerian students toward school subjects, found that girls appeared to consider the utilitarian value of education more than interest compared to boys. School and school work in the finding appeared to have been evaluated more in terms of personal rewards to be gained in the future. One possible suggestion from Abiri's findings might be that, where society adversely discriminates against women in mathematics related expectations and job opportunities, female students in schools might not achieve so well in mathematics.

The present study investigated the effects of sex, ability and method of instruction in a Factorial Experiment design. The study tested null hypotheses on the main and on the interaction effects of sex, ability and instruction method on students' achievement in mathematics. Motivation toward learning mathematics and attitude toward mathematics were among covariates measured for control in the study.

Curriculum and Achievement

A more broad and appropriate conception of curriculum for purposes of this paragraph, might be the one contributed by Featherstone (1959:91). In the conception, curriculum consists of all the experiences which a school offers to the learner for the purpose of achieving certain pre-determined goals. Curriculum in the perception, includes objectives and planned programmes of instruction and evaluation. Tyler (1949) recommended that objectives should always guide curriculum formulation, implementation and evaluation. In formulating instructional objectives, Tyler also recommended consideration of learners needs and the kind of changes needed in the behavior pattern of the learner. Piaget's theory (Copeland , 1974) imports a need to consider learner readiness for the kind of curriculum materials planned for instruction. Learners in this theory grow through phases of readiness to carry out specified mental operations toward mastery of specified tasks and concepts. In the theory, learners in the chronological age range of eleven to fifteen years, are expected to be able to form formal concepts and show competence in abstract thinking and reasoning by hypothesis. Selection of curriculum materials correspondingly needs to take cognizance of the mental developmental ages of the learners. Concepts to be taught must be appropriately matched to the pupil's mental age.

Novak (1970) writing primarily on the learning of biology, thought instructional programmes need always to delineate concepts to be taught and then make deliberate effort to select those instructional materials that provide optimum opportunity for meaningful learning by the students. The assumption then might be that meaningful learning is more likely to lead onto improved students' achievement. Ausubel (1968) made a significant contribution on the concept of meaningful learning. In the contribution, meaningful learning was seen as occurring when new information is presented so as to link up with relevant concepts already existing in the cognitive structure (previous learning). The existing concepts thus become modified into new concepts. Thus in a complementary view, Novak (1970) thought the degree of meaningfulness of what the student learns might vary from student to student depending on the adequacy of the relevant concepts previously learnt. Rote learning in this view (Ausubel, 1968; Novak, 1970) might be expected when the link up between the new and the old concepts is not well completed.

Rote learning on the other hand might be seen as one end of a continuum - meaningful learning to rote learning. Thus rote learning might be seen as occurring in diminishing degrees along the continuum towards meaningful learning depending on the strength of the link between new concepts and previously learnt concepts as suggested by Ausubel (1968).

Novak (1970) suggested that with respect to instructional programmes in Biology, a principal deficiency common to instructional programmes is failure to delineate concepts to be taught and then to select appropriate instructional methods that provide the students with an optimum opportunity to learn the concepts meaningfully. In this view curriculum programmes should put emphasis on teaching well selected concepts

The present study designed a limited curriculum programme for use in testing the study hypotheses. The programme included: introductory materials to the Algebra of Sets and to the Euclidean Geometry of Solid Shapes; heuristic and expository methods of instruction; and relevant specially constructed evaluation instruments were us Deliberate effort was made throughout the study instruction and evaluation of outcomes to follow objectives specially formulated for the purpose in the study (Appendix VI). Previous mathematics learning of the students was evaluated by a pre-test so that subsequent attempts to 'link' new concepts taught in the study to concepts already existing in the student's cognitive structure might be facilitated. Study lesson design (Appendix VI) was more on the basis of concepts, progressively from simpler to more complex ones The foregoing measures and others were aimed at structuring the curriculum to be more meaningful and to maximise students' achievement.

Attitude Studies

Attitude definitions differ (Dawes, 1972:1-17). Newcomb (1966) saw previous experience as an important element in shaping attitude to subsequent situations. Thus students' previous experience in learning mathematics might influence the student's later attitudes toward mathematics. Bieri (1967) came to the view that attitude expression involves evaluation and frequently reflects the same degree of experienced intensity in both feeling and belief about the attitude object.

In the Affective-Cognitive theory, Rosenberg (1967) postulated that one's attitude was intimately related to one's perception of potentialities (beliefs) on the extent to which the attitude object might contribute towards the attainment or non-attainment of one's desired goals. Thus the degree of affect towards the attitude object (mathematics in the present case) should correlate with the intensity of the belief.

Attitude can be measured (Dawes, 1972). However, Allport (1967) cautioned that individuals might have many contradictory attitudes toward an object. Such attitudes might even change when influencing factors change. Consequently, Allport suggested that attitude scales should be regarded as giving the "roughest approximations" of attitudes.

Learners pick up value systems and attitudes from the home experience (Lindgren, 1972), peers, society and school (Peil, 1973). Therefore students' experiences in these social institutions probably also influence the formation of attitude toward mathematics. The Reinforcement Theory contends that attitude changes could also be achieved through reinforced learning (Insko, 1967:12-63). Students' successes in the learning of mathematics therefore could promote a favourable attitude toward mathematics.

If the majority of experiences in the Zambian homes, schools and society project mathematics positively or negatively to the children, then the consequences are likely to be correspondingly positive or negative on students' attitudes and motivation towards the learning of mathematics. Attitude in the present study was viewed as having cognitive and affective components as suggested in Katz's definition (Dawes, 1972:16). The feelings associated with attitude, in this view, constitute the affective while the beliefs form part of the cognitive component. The present study controlled attitude toward mathematics and motivation toward learning mathematics as covariates.

Motivation

Lindgren (1972:21) suggested that motives provide force and direction to behavior. A learning motive therefore appears to be the driving force behind or rather the pulling force toward the act of learning. Learning activities which do not provide opportunity for "immediate self achievement" were noted by Lindgren (1972:205) as likely to have an adverse effect on achievement.

McClelland (1961) identified three main categories of needs which motivate students. These were the need to : (i) achieve. This could bring the joy of being competent and excelling oneself in relation to others. (ii) Gain power of ability to influence others and have control of situations in which this power might be utilised. (iii) Affiliate, belong and be accepted by valued and desired social groups. Consequently, effective learning situations could be organised so as to bring into play these needs of achievement, power and affiliation.

Various factors influence and determine the students' motivation states. One categorisation of these factors might be into "intrinsic" and "extrinsic". The former includes thirst for a particular knowledge. Ausubel (1968 : 365) described this thirst as "the most important kind of motivation in classroom learning". It is probably difficult to generalise on what might or might not motivate learners in a given situation. Thompson and Humicutt (quoted in Klausmeier and Goodwin, 1966) found that the use of "good" as a motivating praise raised the learning performance of introverted children while lowering that of extraverts and vice versa when "poor" was used.

Maslow (1970) on motivation theory, proposed that man should always be seen as desiring something. That these desires are more usually in the nature of means to ends than ends in themselves. Consequently, a study of motivation could be seen as a study of ultimate goals, desires and needs. In this view, fundamental goals and needs might be seen as constituting motivational life. The individual becomes motivated toward a particular desire as an integral whole and not just as part of himself. Maslow thought the desires themselves emerge in a hierarchy of prepotency such that the emergence of one desire as dominant follows satisfaction or dissatisfaction with other previously prepotent desires. Maslow (1970:27) however cautions over too much reliance on results of animal experiments in formulating motivational theories. The basis of the caution includes concern over the natural differences between animals and man which are also manifest in the phenomenon of motivation.

School achievement might satisfy the learners needs for: (i) acquiring certain kinds of knowledge and solving certain kinds of problems; (ii) ego-enhancement; (iii) affiliate to or gain approval of super-ordinate person(s) (Ausubel, 1968). Thus motivation is one of the important prerequisites for improved achievement. Encouragement and incentives rather than punishment might better improve learners' motivation toward improved achievement.

Socio-Economic Status and Achievement

From birth, the human baby reveals a curiosity to explore the self and the surroundings giving meaning to the encounters experienced. Holt (1974) suggested that the child first encountered space as informally arranged. The child's imaginations then rise as the child gives own meanings and makes own arrangements of objects encountered. Out of the objects and the environment, the child creates imaginary sceneries of action in play. These imaginary experiences according to Holt, become real things for the child to talk, to think and to argue about with others. Experience of the kind, introduces the child to some fundamental thinking processes in logic and mathematics. The processes then develop into Piaget's (Copeland, 1974) kind of logico-mathematical structures. The latter structures are necessary for good achievement in later school mathematics learning. Homes need to provide the challenging environment which propels the child into experiences of the foregoing kind. Well-to-do homes on the higher socio-economic level in society, might have more apprecia- tion of this need and have the means to provide the child with such stimulating experiences more than the poorer homes on the lower socio-economic strata of society.

Ferron (1980) thought that mathematics like language which is natural, also represents a way in which man communicates with his environment. Ferron noted that children naturally experience motivation to explore mathematical concepts of number, space and shape relationships in the surrounding environment. Through explorations, the child learns much of these relationships on it's own. Ferron however thought that the provision of an appropriately challenging environment was determined to a large extent by the socio-economic status of the home as well as that of the community in general. In developing countries such as Zambia, limitations in available economic resources could limit, in many families, the provision of adequate and appropriate toys, games and the necessary stimulations in the home environment.

Kapambwe (1980) studied the relationship between home background and scholarstic achievement among Zambian Junior Secondary school students. The socio-economic variables Kapambwe studied included parental education, occupation and income. The study found significant differences between the scores of the high and of the low achievers. Kapambwe accounted for the difference in terms of the socio-economic status of the home of the students. Unfortunately, literature reviewed did not appear to have direct studies of the effects of the socio-economic status of the students' homes on secondary school mathematics achievement in Zambia.

One foreign reported study of the relationship between socio-economic status of the students' homes and students' achievement in mathematics was done by Husén et al. (1967). Secondary school students of twelve developed countries were involved. The study found that the performance of the students "on the mathematics tests was consistently related to father's and mother's education and father's occupation" (Husén et al., 1967:301). The study report commented that school achievement in mathematics "is well known" to relate to student' socio-economic background. On primary school level problem solving in arithmetic, Bujan-Delgado (1982) found that primary school children from higher socio-economic status homes scored significantly higher than those from lower socio-economic status homes in Costa Rica. Does socio-economic status of the homes of Zambian secondary school students influence their achievement in mathematics ? If the socio-economic status of the student's home proved to have adverse effects on school achievement, the school might then be required to play a compensatory role to the less fortunate pupils. The school might then have to try and provide the experience which the home failed to provide thus resulting in the adverse effect. The present study, controlled as a covariate the effects of the student's home socio-economic status on student's achievement in mathematics.

Primary School Teacher Problems

Students' achievement in mathematics might also be influenced by a number of factors relating to teacher characteristics. Teacher mastery and effective presentation of lesson material are some of the factors. Teacher training might improve teacher performance in the foregoing aspects.

Gagne (1975) , in a primary school teacher training inspector's report for Zambia's National Education Reform exercise, commented as follows. In 1973, twenty one percent of the primary school teachers had no professional training. The academic qualifications of sixty four percent were either Grade Six or Grade Seven. Thirty four percent had only passed Grade Eight or Nine. Thus very few had Grade twelve or its equivalent.

Gagne observed that thirty five percent of the 1973 teachers in service had probably been trained before Zambia's independence in 1964. In pre-independence Zambia, Gagne noted that, admission qualification into primary school teacher training was only Grade Seven. Professional training thereafter, if found, took the form of a one year crush course. Gagne commented that the course was terminal, pre-service and "strictly traditional in both outlook and organisation". The comment further described the training as having consisted in "intensive drilling" and "traditional" methods.

However, Gagne acknowledged that the quality of the teacher training improved when the minimum admission qualification requirement into the primary school Teacher Training Colleges was raised to Form III (Grade Ten) after Zambia's independence. Gagne still complained that the colleges "had little impact on development of learning in the primary school". The colleges, were more of "servants rather than teachers in curriculum development". The actual training in the colleges was said to be still "based on traditional rituals, untested assumptions and dubious criteria" (Gagne, 1975:8-9). The colleges were said, not even to appear ready to "conceive of a course outside the traditional formular". The professional experience of most college staff as well as the qualifications of this staff were said to appear wanting.

The effects of a defective teacher training programme might continue showing for many years later through a multiplier effect adverse to good teaching and successful student learning. Intervention of corrective measures becomes necessary. The situation reported by Gagne as obtaining in 1975, if validly described, might have not significantly changed by 1979. In that year, most of the present study sample students probably entered Grade One. Waddimba (1982) found Zambia's inservice teacher training remedial measures for the primary school level still inadequate.

English Medium of Instruction

Vernon (1950:39-40), after a review of factorial studies, noted that the classification of mathematics attainment readily showed linguistic and mathematical-scientific ability components. In Zambia, Chishimba (1980) found that there was a divergence of Zambian public opinion in 1969 when English became widely prescribed as medium of primary school instruction. Chishimba thought English was not even a second language for the primary pupils. Shana (1980:15) study of circumstances which led to the choice of English as a primary school medium of instruction, concluded that the choice was "apparently more for political and administrative reasons rather than for educational consideration". Chikalanga (1983:3) reviewed various studies

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concluded that the studies appeared to agree that the Zambia Primary Course English component had "failed to deliver the goods". Chikalanga found the standard of English among primary school pupils to be apparently low for varied reasons, which included faulty teaching methods. Chishimba (1980) had also observed that pupil proficiency in English among Zambian primary school pupils appeared declining. According to the observation, the teaching profession had also recognised that "the pupils who enter Form I (Grade Eight) are deficient in writing skills and handling English structure in connected discourse". The decline in pupil competence in English was also identified as being in "speaking and writing skills".

Lawrence and Sarvan (1983), in a limited study of English usage in Zambia, suggested that Zambian primary school pupils probably evelved an "interlanguage" of their own on being first taught English. The suggestion described *an interlanguage as a transitional form of language which in the case of Zambian primary school pupils,* might be "similar in many respects" to English "but also similar to the "first language" of the Zambian pupil. Lawrence and Sarvan tentatively concluded that there appeared to be an overall acceptance of some form of "non-standard" English among Zambian speakers. Chishimba (1980:44) had also found that most Zambian primary school teachers were "imperfect speakers of English", unable on their own to "bring about a generation of better English speakers than themselves". If the foregoing observations on the English language medium problem in Zambian primary schools were valid, pupils in the schools could also be experiencing mathematics achievement problems related to the English medium of instruction.

Zambian studies on the relationship between English language medium of instruction and students' achievement in mathematics, might have been useful to the present study, but were scarce in the literature.

Culture Associated Studies.

Witkin (1967) hypothesised that cognitive styles might be categorised along a continuum of Field-dependent (FD) to Field-independent (FI). Cognitive style in this view, was seen as "the characteristic self consistent mode of cognitive functioning found pervasively throughout the individual". The kind of style acquired by the individual, in this view, is determined by socialisation practices in the culture in which the child was reared. Variations in the socialisation practices according to sex, might therefore be expected to show in differing cognitive styles between males and females. The FI individual, according to Witkin's hypothesis, is articulate in his/her perception and thinking as when dealing with symbols representing concepts in language and mathematics. The individual readily imposes structure on unstructured fields and perceives items as discrete from organised ground when the field has been structured. The FD on the other hand is global in perception and finds difficulty in imposing structure or differentiate items even when the field has been structured. Berry (1966) and Dawson (1967) found evidence of support for Witkin's hypothesis even among Africans.

FI cognitive style, in Witkin's view, is more likely to develop from cultural socialisation in which parents encourage the children towards separation, autonomous functioning and so on. The manner in which parents impart value systems for internalisation including the way they deal with the child's expression of impulse were also seen as providing evidence of Witkin's assertions.

One inference from the foregoing could be that FI students should achieve better in school mathematics than FD students all else being equal.The inference might be expected if learning of the largely abstract mathematics concepts and solving related problems, were assumed easier to a cognitive style more articulate in perception and re-structuring of component parts than to one less articulate.

Ferron (1980) observed that children show a natural inclination to explore number, space and shape relations.

However, he observed that in the third world a suitably appropriate challenging environment to stimulate such explorations is often lacking. Such an environment which might develop abilities related to mathematics might include appropriate toys, games and parental guidance of children during play. Goldberg (1970) in a study of infant care and stimulation in homes in the Matero suburb of Lusaka, Zambia, found "little intentional developmental stimulation or concern for intellectual ... development" of children in the homes and the surrounding community. Goldberg found that the homes had little indoor space for the children to play in. Infants were found to be "almost constantly with a care taker" and frequently carried on the back in a cloth sling. The sling was found to serve as a "cot, playpen, buggy and feeder" for the first year of age.

Infant rearing practices of this kind might be expected to contribute toward the development of Witkin's FD cognitive styles. Goldberg further noted that very few mothers appeared to follow feeding time schedules. Perhaps such irregularity might deprive the child of an opportunity to develop, at the early age, aspects of the concept of time. In another observation, Goldberg thought no "mother bought toys with an eye to developing" intellectual skills. Only four out of twenty five infants studied were found with toys of any kind. The toys found were largely dolls, balls, toy dishes and cars. The infants were found to play generally with sand, tins, crockery, water, sticks, stones, bottle tops, boxes and pieces of cloth. There was little "messy" play allowed. Verbal learning in which the children repeated names of objects was also lacking. The study, by Goldberg, observed that the generally low education of the mothers was probably partly responsible for the shortcomings of this infant environment. The sets of toys and games which occupied the children in Goldberg's study were probably not the best for the mental preparation of those children for the kind of school mathematics they were to learn.

Perhaps the kind of play things that stimulate children into actions which develop logico-mathematical abstractions such as numeration, classification, ordering, transitivity and so on need to have specially relevant and appealing features. Perhaps the child needs to find the objects, necessary to induce physical and mental actions, in fair quantities in the environment to induce say, counting. Challenging varieties of assortments of the objects, in a variety of colours might be necessary for classification and so on. A mere random existance of a doll or a ball or of dull irregular objects in a collection such as of stone, stick and other junk as toys and for games, might not adequately offer the necessary attraction and stimulation to have the objects counted, classified, compared and so on in physical and mental actions toward acquiring some logico-mathematical abstractions and structures. Parental awareness of these mental needs as well as having the financial capacity to buy the objects selectively , or skills to make the objects attractively, so that the infants are adequately provided with the play objects could be crucial factors in later mathematics learning.

Munro (1968) in another study of children in a Lusaka suburb also made similar observations as Goldberg (1970). Munro found that the boys were allowed more freedom than girls to engage in a variety of games and activities away from the home. The girls appeared in the study to be more subjected to routine chores in the home. Munro thought such routine chores unlikely to prepare the children adequately in skills future school learning was to require. Cultural differentiation of the above kind could handicap girls in future school mathematics learning.

Munro also found that "objects specially designed for the exercise of developing skills" and pictorial stimulation were lacking. The provision of toys, pictorial books and writing materials for the children also appeared largely lacking. Munro attributed this to possible parental attitudes and levels of education besides limited financial resources. He also thought that cultural practices of keeping the child ever close to the mother at the expense of more task oriented and independent child activities, denied the children adequate exposure to learning skills and values which the school will require. *The parents also did not appear to intervene much to guide* their children in developing the skills necessary for school. Instead, the parents appeared to stress conformity with no emphasis on skill stimulation. Circumstances of the kind appear similar to those Witkin (1967) thought might develop FD cognitive styles.

Wober (1975) reviewed psychology studies in Africa. Wober observed that "perspective built into" the drawing of an object such as size or space between objects to show distance "can lead to misidentification" in persons who grow in some African cultures. Wober felt that this could result from African cultures being "non-visual". Africans affected could thus miss being trained in interpreting such builtin perspectives common to western cultures. Mathematics taught in Zambian schools probably assumes training in such interpretations. Wober described non-visual cultures as those which used more conversation, story telling, performing arts and so on rather than writing and pictures for interaction and storage of information (Wober, 1975:108).

Dawson (1967:115) noted that "a number of writers" reporting on studies of "African spatial - perception processes " have commented that some Africans appeared to experience difficulty in their "perception of spatial relations". Included in these tests however was perceiving complex shapes and "Block Designs" forming subsets of western oriented Wechsler Tests. There was also a test on pictorial perseption . On the latter test result, Dawson noted that a suggestion had even been made that Africans who had not been to school appeared to be "two-dimensional".

In a study of Zambian primary school children, Okonji (1972) found that these children had problems in handling spatial relations. Serpell and Derogowsky (1972) also found that only a quarter of their Zambian Grade Seven student sample appeared to have adequately mastered the convention of three dimensional representation. The conclusion was based on the result of a post test after using class books, pictorial materials and films to teach pictorial depth perception.

Some Zambian studies also investigated the competence of primary school children in number work. Sharma and Henderson (1974) found that grade three pupils in Zambia had not mastered number skills and consequently experienced difficulty in keeping pace with the mathematics course. The study found that the children often failed to adapt addition and multiplication skills to simple problems expressed in a different form. Kingsley (1975) studied how Zambian pupils developed strategies for doing intellectual work. The pupils were from "relatively older" established homes of civil servants. The ages ranged from seven to ten years. The study found that these pupils tended not to use rudimentary quantitative strategies, they learnt earlier, when faced with related problems. In one instance, the pupils were required to say how many blocks there were in a structure which visibly had less than ten of these blocks. Kingsley thought the pupils could have just quickly counted the blocks, but most did not though free to do so.

More direct Zambian studies on the effects of Witkin's hypothesised Field-dependence versus Field-independence on instruction and achievement might have been useful to the present study. However, literature did not appear to have related research. Similarly, an investigation on how a change from Field-dependence to Field-independence might be effected might be necessary if Witkin's hypothesis were valid.

Summary of Literature Review

The present study literature review focussed mainly on Zambian studies. Foreign studies were reviewed only to supplement Zambian studies or fill gaps where no Zambian studies were found in the literature.

The growth of mathematics teaching in Zambia since independence in 1964, appeared to have been challenging. The challenge was taken up by the Zambia Ministry of Education with determination to succeed. However, about two decades later there was apparently still much more to be done. Students' achievement in mathematics at the primary, secondary and university levels of Zambian education appeared still unsatisfactory. Probably the upgrading of primary school teachers of mathematics and English are among needed imperatives towards improved students' achievement in mathematics. Perhaps the use of

English as medium of instruction in some early Zambian primary school grades needs further study as some studies reviewed appeared to raise concerns over the practice.

Students'achievement in mathematics in the literature reviewed, appeared dependent on a number of variables. The variables appeared to include: learner and teacher characteristics and behaviours; curriculum organisation and presentation to learners; student's home characteristics; and mathematics related experience the student might have gained from home and from previous mathematics learning.

Notes

1. Republic of Zambia, Ministry of Education, Annual Report 1964. (Lusaka : Government Printer, p. 31)

2. Annual Report 1964 : 67-70.

3. Annual Report 1964 : 69.

4. W. Banage; E.F. Bartholomeusz; R. Henkel; e. M. Lungu; and C.D. Yandila, " Draft Report of a study of students' performance mathematics in relation to the students'performance in other courses offered at the University of Zambia. Copy in the Special Collections Section of the University of Zambia Library, Lusaka.

5. D'Ambrosio Ubiratan "Adequate Mathematics for the Third World Countries" in Eltom, M.E.A (Ed.), Developing Mathematics in Third World Countries (Amsterdam : North Holland Publishing Company, 1979 : 33 - 46).

CHAPTER III

METHOD

The study design deliberately attempted to keep the theoretical framework and the hypotheses of the study in congruence with the methods used. The chapter on method discussed population, sample, instruments, instruction, control of variables and data analysis.

Population

The study population consisted of the entire 1986 Grade Eight student intake of Kabulonga Secondary School for Boys and Kabulonga Secondary School for Girls, Lusaka, Zambia. Kabulonga Boys and Kabulonga Girls Secondary schools are unisexual schools under the same centralised government school system in Zambia. The two schools are situated on adjacent plots in the same community area. In physical structures, the two schools appeared to be equivalently built. Both schools, appeared to enjoy equal social prestige from a common pre-independence history of Zambia, of having been special schools for the priviledged children of the colonisers. Presently however, the schools' intake of students, estimated to total about 1000 in grade eight for the two schools in 1986,[1] is from all social strata of Zambia. This has become possible under Zambia's education policy of free and equal education for all. Students' performance in mathematics at the Ordinary Level (Grade Twelve) examinations however, was thought to be better in the Boys' than in the Girls' School.[2] However, the factors of common history, prestige, environment and others were considered in the present study, necessary in reducing between-schools variance.

The study population referred to above, was preferred because a new intake of Grade Eight students appeared to be appropriately a new set of <u>tabula rasa</u> initiatees into the Zambia Secondary School Mathematics Course. The population was chosen because of having been recently graded in ability by the Zambia National Grade Seven Composite Selection Examination. This examination is probably the best standardised test measure for estimating ability in Zambia at that level of schooling. The students' estimate average age of fifteen years[3] appeared to place the students at Piaget's phase of Formal Operations. This enabled the study to use this Piagetian frame of reference in the study's conceptual framework.

Piaget's theory (Piaget, 1969), postulated the following phases in a child's mental development:

(i) Sensory-motor phase covering the period from birth to about two years of chronological age. During the sensory-motor phase, innate reflex actions instead of thought processes dominate.

(ii) Pre-operations' phase is expected from about two to four years of age. Classification of concrete objects by a single feature is one important characteristic of the phase.

However, from four to seven years of age intuitive thinking should appear along with indications of the beginnings of conservation.

(iii) The phase of concrete operations is expected from about seven to eleven years of age. Reversibility and conservation should then be achieved during this phase.

(iv) The final phase of formal operations should begin to show from about eleven to fifteen years of age. The adolescent should then begin to show ability to think in the abstract, reason by hypothesis and understand symbolic relations.

In the Piagetian model of intellectual development, assuming chronological age strictly delineates phases, the present study students should be at the phase of Formal Operations. The expectation is on the assumption that formal operations commence from between eleven and fifteen years of age. However Nkwanga (1982), found that a Piagetian phase might tend to appear later among Zambian primary school children than in Piaget's Geneva results. Imenda (1980:15) after a review of related literature, concluded that "a good number of Zambian secondary school students as others elsewhere, might" be functioning at a lower level of intellectual development than Piaget's level of Formal Operations.

Perhaps, where the environment of the home and the community failed to stimulate a child's full development through Piaget's phases, the school ought to step in to correct the situation. Otherwise, equal opportunity for all children in school might be difficult to realise.

Sample

The study sample was constituted by stratified sampling of students from the intake list of each of the two study schools. Two study classes were then formed for each sex by random assignment of the students from the list obtained by stratified sampling. The two resulting study classes for each sex, were then randomly designated, one as an experimental class and the other as a control class. More details of the procedure followed to accomplish the foregoing sampling now follow.

The entire 1986 Grade Eight intake list of each study school was used for the sampling. In the Boys' School to start with, the forty topmost students in aggregate scores in the Zambia National Grade Seven Composite Selection Examination on the intake list were designated "high ability" boys. The forty bottom-most in aggregate scores on the same intake list were designated "low ability" boys. The forty high ability boys were then randomly assigned to form the first halves of the two planned boys' study classes. Similarly, the forty low ability boys were then randomly assigned to provide the second halves of the two boys' study classes being formed. Thus two boys' study classes of forty students each had been formed. Each of the two classes had an equal number of high ability and of low ability boys. The two boys' study classes were then randomly designated, by tossing a coin, one as an experimental class and the other as a control class. In the study, the experimental classes were taught by heuristic instruction while the control classes were taught by expository instruction. (See Table 1 for score ranges).

Exactly the same procedure as for the formation of the boys' experimental and control classes, was followed in forming a girls' experimental and a control class from the 1986 Girls' School intake list. Thus four study classes of forty students each had been formed. Two of the classes were in the Boys' School and the other two were in the Girls' School. Thus each school had an experimental and a control class. Each of the four classes had twenty high ability plus twenty low ability students.

On the 17th February 1986, when the selected new Grade Eight students of the two study schools reported for first lessons, some of the expected study sample subjects did not turn up. Unexpected new students filled up the vacances. Slight changes of this kind kept on affecting the size and composition of the four study classes throughout the five weeks study period of instruction at the schools. Thus the number of students in some study classes had changed slightly by the end of the five weeks. The following measures were then followed to make the sample category subgroup numbers in each study class the same again. This equality of category subgroup student numbers was imperative for the Factorial Experiment of the study design to remain orthogonal.

The unexpected new students were allowed to stay in the study classes. However, data collected from such students was not used in the study. Random reductions, using the table of random numbers, were used to even up the category subgroup student numbers in each study class. Participating sample subjects in each study class were now consequently reduced to 24. This was the highest possible number in the circumstances. Twelve of the students in each class were of high ability while the other twelve were of low ability. All twenty four students in each of the study classes belonged to the original randomly assigned students to the class.

Table 1 provides more descriptive data of some study sample students' subgroup characteristics. The sample subgroups ability (Grade Seven Aggregate mean scores) were also compared on the table. Comparisons made were between corresponding ability levels of the sex categories and also between the two study category levels of ability in each sex group.

SCORES COMPARED	DESCRIPTION OF STUDENT SUB-GROUPS COMPARED	NUMBER OF STUDENTS	SUBGROUP ABILITY SCORES				STANDARD DEVIATION	STANDARD ERROR	t - RATIO
			HIGHEST	LOWEST	RANGE	MEAN			
Male/Female high ability	Male students categorised as high ability	24	786	737	49	754.58	12.62	2.576	4.639, df =46 significant at p=0.001
	Female students categorised as high ability	24	795	711	84	729.42	23.39	4.773	
Male/Female low ability	Male students categorised as low ability	24	675	671	4	672.83	1.20	0.245	50.06, df =46 significant at p=0.001
	Female students categorised as low ability	24	658	655	3	656.46	1.06	0.2169	
Male high / low ability	Male students categorised as high ability	24	786	737	49	754.58	12.62	2.576	[illegible], df =46 significant at p=0.001
	Male students categorised as low ability	24	675	671	4	672.83	1.20	0.245	
Female High / low ability	Female students categorised as high ability	24	795	711	84	729.42	23.39	4.773	15.263, df= 46 significant at p=0.001
	Female students categorised as low ability	24	658	655	3	656.46	1.06	0.2169	

In the table, the dispersion of the scores appeared larger for the high ability female subgroups than for the high ability male subgroups. The dispersion of the low ability subgroup scores of either sex did not appear to differ much. The table showed that a female student had the highest ability (Grade Seven Aggregate score) of 795 in the study sample and that another female student had the lowest score of 655 in the sample. In the original combined male and female score list of ability, there were two female scores (795 and 789) which topped the list. On the other hand, the ability score of every female low ability sample students was lower than the ability score of every male low ability sample student. The latter was expected since the Grade Eight selection cut-off points for male and for female students differ in the Zambian education system. The differences are discussed under the next subheading. However considering the summary result in Table 1, the ability scores of the male students were sandwiched between female ability scores.

Never-the-less, the foregoing result summarised in Table 1, does show that the Grade Seven Aggregate score ranges used to categorise both the male and female sample students into high and into low ability subgroups varied. The t-ratio summary data in the last column of Table 1 indicated some of the margins of the variation. The interpretation later, of the main study result therefore had to take recognisance of this observation. Table 1 t-ratio comparisons of ability (Grade Seven Aggregate score) value means of the study male and female sample subgroups categorised as of high and as of low ability also revealed the following. The ability mean scores of the high and of the low ability male subgroups were significantly higher than the ability mean scores of the high and of the low ability female subgroups respectively.

Ability Measure for the Present Study.

Ability for the purpose of the present study, was measured by the aggregate scores of the sample students in the Zambia National Grade Seven Composite Selection Examination. The examination serves for , certification of primary school leavers and for selection from the Grade Seven completers a limited number for filling the few available Grade Eight places in the Zambian schools. Annually less than twenty percent usually become selected. Selection is based on the aggregate score of a candidate in six equally weighted test papers of the Grade Seven Examination. The tests are in English language, social studies, mathematics, science, verbal reasoning and non-verbal reasoning. Selection cut-off points vary on the Aggregate Scores' list according to the number of Grade Eight places available, sex, education region of Zambia and whether the school is a day or a boarding school.[4]

Sharma (1974) in a study of the Grade Seven Composite Selection Examination, noted that the predictive power of most of the six papers was poor. Sharma commented that there "seems to be a dissonance" between primary and secondary stages of education in Zambia even in the same subjects. The mathematics marks of a sample of the 1972 Grade Seven examination candidates, were found to correlate only 0.460 with later marks in Grade Nine in a specially devised criterion examination in mathematics. Sharma concluded that a student's performance in the Grade Nine level mathematics could not be confidently predicted from the Grade Seven Composite Examination student's performance in mathematics. Of the Grade Seven six papers, Sharma found the verbal reasoning test paper "to be the best single predictor, than all the six papers taken together" (Sharma, 1974:18).

In an earlier reported study, Ming (1973) had found non-verbal reasoning test to be the more "useful and valid predictor" of secondary school students' performance in technical courses than other Grade Seven Examination papers. Sharma (1974) had also found that candidates' performance in certain Grade Seven test papers, including mathematics, was "a function of brute recall and low level application" of what was learnt.

The present study focussed on the mathematics achieve- *ment of students beginning the Zambia Junior Secondary School mathematics course. Students' performance at the*

Grade Seven Examination mainly became relevant in helping define ability - one of the main independent variables of the present study.

Design

The study was designed to investigate the main and the interaction effects of independent variables (non-metric factors) method of instruction, ability and sex, on the dependent (criterion) variable Students' Achievement in Mathematics (SAM). The effects on SAM - also regarded as important - of the metric covariates : previous mathematics learning; motivation toward learning mathematics; attitude toward mathematics; and home socio-economic status were controlled.

Therefore, the design used was essentially a 2 x 2 x 2 Orthogonal Factorial Experiment incorporating control of the effects on SAM of the four covariates listed above. Since the study main focus was on the effects of the non-metric factors and control of the covariates, the design might be regarded as an Analysis of Covariance (Nie et al., 1975:399). The design also used a fixed effect or linear hypothesis model in so far as all the factors were considered as fixed. This was convenient since the Fisher-ratios output of the Analysis of Variance (ANOVA) of the subprogram used also assumed a fixed effect model (Nie et al., 1975:399). The main features of the present design therefore, included experimental versus control groups, randomised subjects and pretest versus posttest measures.

The experimental subgroups were taught by heuristic method of instruction while the control subgroups were taught by an expository method of instruction. Randomisation of subjects commenced with a stratified selection followed by random assignment of the selected subjects to constitute two study classes for students of each sex. The two classes of randomly assigned subjects of each sex were in turn randomly designated as experimental and control classes. Pretest scores provided measures of covariate 'previous mathematics learning' while posttest scores provided measures of the criterion variable SAM. Random assignment rather than random sampling was used in the foregoing so as to ensure that category subgroup students of the study sample were evenly distributed over all the study instruction classes. Thus equal cell data analysis frequencies, making the factorial design orthogonal, were more assured.

Realisation of the orthogonal character of the design, enabled the total variance to be regarded as distributed according to the 'sum of squares' equation :

$$SS_{total\ variance} = SS_{between} + SS_{interaction} + SS_{within}$$

Therefore, since in the factorial design of the present study each cross classification among the study factors has the same number of cases, all factor effects were regarded as orthogonal. The implication was that the effect of each factor was considered independent of the effects of other factors. Interaction effects were also taken as orthogonal (independent) of the effects of the main factors (Nie et al., 1975:398-433).

The diagram below shows the application of treatments on the various subgroups of the Factorial Experiment design of the present study.

FIGURE 1

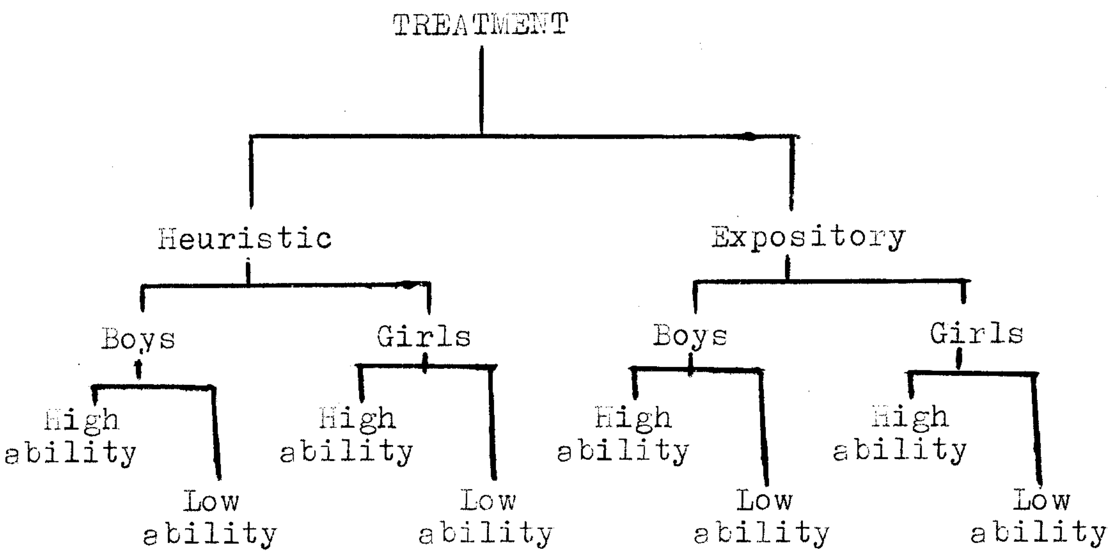


DIAGRAM ILLUSTRATING TREATMENT APPLICATION OF STUDY DESIGN

The factorial design used, enabled the three independent variables method of instruction, ability and sex, to be juxtaposed for purpose of studying the variables' main and interaction effects on the dependent variable Students' Achievement in Mathematics (SAM). Advantages of the design also include the following.

(i) Being able to plan, manipulate, control and analyse the simultaneous operation and interaction of these many variables at the same time.

(ii) Precision of the factorial analysis over one-way analysis of variance.

(iii) Being able to hypothesise and test interaction effects of independent and dependent variables (Kerlinger, 1973: 242-269). The design is probably unique in being able to provide a combination of advantages of this kind.

The present study design as a functional relation, could be viewed in the following way. If SAM depended on a set of : teacher characteristics and behaviours (t); mathematics materials taught (m); and student characteristics and behaviors (s); then if other possible covariates were controlled, the mathematical model of the present study based on Henderson's (1963) function model for a teaching experiment T(x, y, z), could be written

SAM = F(t, m, s) as a general function.

Then SAM = f(t, s) as a particular function model of the present study, where:

'm' the mathematics material taught was the same for all sample groups. In the present study these materials were introductory to the Algebra of Sets and to Euclidean Geometry of Solid Shapes.

't' the teacher characteristics and some behaviors were kept the same by having only the researcher give the study instruction in person. Except that only the instruction method behavior was varied from heuristic to expository.

's' the learner characteristics were varied from high to low ability and from male to female.

SAM the criterion measure of student behaviour under the effects of 't' and 's' while 'm' is kept constant was the present study dependent variable. Covariates previous mathematics learning, motivation towards learning mathematics, attitude towards mathematics and student's home socio-economic status were selected for priority control as most important among many others. Stratified random assignment of sample subjects to study sample subgroups was assumed would take care of any other learner characteristics otherwise not taken care of in the study design.

Types of Data

The following data were collected.

(i) Pretest mathematics achievement scores for all study sample students. The pretest scores were assumed to be interval data and were used as measures of the metric covariate 'previous mathematics learning'.

(ii) Posttest mathematics achievement metric scores for all study sample students. The posttest scores were assumed to be interval data and were used as measures of the dependent variable Students' Achievement in Mathematics (SAM). The posttest measured the cognitive outcome of the study instruction methods. The scores were used to test all the study null hypotheses and their alternatives.

(iii) A specially constructed study Attitude Scale was used to obtain attitude scores for all sample students. The scores were assumed to be interval data and used for the control of covariate 'attitude toward mathematics'.

(iv) A specially constructed study motivation scale was used to obtain motivation scores for all sample students. The scores were assumed to be interval data and used for the control of covariate 'motivation toward learning mathematics'.

(v) A specially constructed study'home socio-economic status' scale was used to obtain students' home socio-economic status scores for all sample students. The scores were assumed to be interval data and used for the control of covariate 'student's home socio-economic status'.

(vi) Non-metric two level norminal data for each of the independent variables method of instruction (heuristic versus expository), ability (high versus low), and sex (male versus female).

Instruments

Five instruments were specially designed, constructed, pilot tested and administered to collect the data listed above. The instruments respectively measured : previous mathematics learning; students achievement in mathematics (SAM); motivation toward learning mathematics; attitude toward mathematics; and student's home socio-economic status.

Deliberate effort was made, in developing each of the instruments, to use appropriate procedures aimed at attaining satisfactory levels of validity of the instruments. The measures included (i) developing the instruments in pre-study actual teaching situations.

For the purpose, the researcher took up temporary normal mathematics teaching in a local secondary school.

(ii) Conducting pilot studies in which the 'test of internal consistency' was used as the criterion for selecting scale items for use in the main study. Scale items selected this way were those of the motivation, attitude and socio-economic status scales. In the use of the internal consistency test for selecting items the procedure was as follows. The total score (X_t) of the top scoring 27 percent of the pilot sample subjects per item on each scale was compared with the total score (X_b) of the bottom scoring 27 percent on the same item. Items with values of $X_t - X_b$ above a chosen limit were selected. The limit was set such that a reasonable number (about 20) of items could be selected for each scale. Kerlinger (1973:451-452) found that "reliability is the internal consistency of a test: the test items are homogeneous", which implies the test is accurate and valid to that extent. (Limits on pages 91-101).

(iii) Taking into account some correlation and/or reliability coefficient values calculated for each scale to indicate validity of the scale.

The standard set for pilot study reliability and/or correlation coefficients indicating acceptable validity was $r = 0.70$. A reliability coefficient of 0.70 or higher "would mean that the test was accurately measuring some characteristic of the people taking it" (Bruning and Kintz, 1968 : 191). In a somewhat related context, Kerlinger (1973:451-452) argued that the square of the coefficient of reliability could be seen as a measure of the percentage of total variance which is "true variance". Thus the higher the value of the reliability coefficient, the higher would be this percentage. Thus r = 0.70 represented approximately 50 percent of true variance in the foregoing view. Considering that : the present study scales were newly constructed and in need of further development and rechecking beyond the one check of the pilot test; students were probably not so fluent in the language (English) medium in which the scales were written; and other factors, the coefficient value of 0.70 appeared fairly reasonable to set as a standard in the circumstances.

Item selection for the pretest and for the posttest scales was aided by a computer output of the Statistical Package for Social Sciences (SPSS) sub-program Pearson Correlation (Nie et al., 1975:276-300). For each of the two instruments, the subjects' scores on each item were correlated with the subjects total scores on the instrument. The computer output consisted of a square matrix of Pearson correlation coefficients for the selection for each instrument. The objectives of this kind of item selection were (i) to select items which correlated most with the total scores on the instrument. (ii) Reduce the number of items further by selecting representative items from the correlated subgroups of items.

The present researcher, when drafting the study instruments, took up temporary normal mathematics teaching at Leopards Hill Secondary School (LHSS) Lusaka. One objective was to gain ideas from interaction with LHSS staff and students on matters related to mathematics teaching and learning. Experience gained at LHSS helped the initial development of content for the present study instruments in readiness for pilot testing.

However LHSS, unlike the study government schools offering education free to Zambian students mainly, was a private school charging school fees and also catering for a fair number of non-Zambian students. LHSS students therefore largely came from wealthier homes some of which were non-Zambian homes. Differences of the kind between LHSS and the study government schools were not desirable for developing an instrument more appropriate for use in the study government schools. However later study pilot tests of the draft instruments conducted in appropriate government schools might have corrected the situation.

Pilot testing conducted later used two Grade Eight classes, one girls' and another boys', at Matero Girls' and Matero Boys' Secondary schools respectively. Both schools were in Lusaka. The pilot tests were conducted from 14 October 1985 to 25 October 1985.

The two pilot secondary schools were selected because, like the study schools Kabulonga Boys' Secondary and Kabulonga Girls' Secondary schools, the two pilot schools were: unisexual; fairly large in enrolments; and both in Lusaka under the same Ministry of Education management conditions. The community surrounding the pilot schools appeared fairly homogeneous in terms of socio-economic status. In a similar way, the community around the main study schools also appeared homogeneous. However, the pilot schools were probably situated in a community of lower socio-economic status compared to the community of the main study schools. Never-the-less government schools in Zambia, such as the two pilot and the two main study schools, draw their intake of students from the same Zambian communities irrespective of socio-economic status. This became possible because the provision of free education in Zambia's Government Schools, largely removed school fees which could have been a social class barrier into schools charging high fees. The pilot testing of the present study instruments at the Matero schools rather than at the Kabulonga schools was therefore on the whole immaterial though convenient for the study at the time.

In the paragraphs which now follow, each of the instruments will be briefly presented together with any additional measures, to the earlier generally stated, taken to enhance the validity of the instrument being presented. The instruments are presented in the order posttest, pretest, motivation, attitude and socio-economic status.

<u>Posttest Scale</u> The posttest instrument (Appendix I) collected measures of the study criterion variable Students' Achievement in Mathematics (SAM). The instrument was designed to test : knowledge, understanding, abstraction and skills; application and generalisation of the knowledge, understanding, abstractions and skills to new situations involving computations and problem solving using number and symbol; and evaluations by making judgements such as true or false, equal or unequal, larger or smaller and so on, to mathematics statements presented. The posttest content materials were drawn from introductory materials to the Algebra of Sets and to the Euclidean Geometry of Solid Shapes. The instrument was aimed at testing outcomes of teaching differing sample subgroups by heuristic and by expository methods of instruction. The posttest items varied from multiple choice objective type questions to computations and problems for solution. The answer scripts were scored on an ordinary point marking system normally used in school achievement tests.

Face and content validy were given attention as suggested by Gronlund (1981) for achievement tests. Determination of (i) subject matter topics covered and (ii) responses the students were intended to make to the test questions on these topics were specifically indentified. The two were then compared to the domain of achievement to be evaluated. The comparison was done in an attempt to check on relative emphasis given in the instrument to content areas in relation to instructional objectives.

The selected pilot test items were all reduced into simple component units. The units were given new serial numbers. The correlation of odd numbered item scores and even numbered item scores gave a 'split-half' reliability coefficient of 0.83 indicating the level of the internal consistency of the posttest instrument. That is , indicating that the test items were to this extent homogeneous (Kerlinger, 1973:451-452).

Pretest Scale The pretest instrument (Appendix II) was designed to be equivalent in all respects to the posttest instrument just described above. The pretest was intended to measure the previous mathematics attainment of the sample subjects in the mathematics subject matter on which study instruction was to be given. The rationale for the pretest included the fact that the sample subjects came from different schools expected to have taught them something on the introductory topics to the Algebra of Sets and to Euclidean Geometry of Solid Shapes. Some of these topics are included in the Zambia Primary School Mathematics Course. The sample subjects were expected to have covered this course in the primary school. However, considering variations in teaching coverage which the sample subjects might have experienced, previous mathematics learning was thought an important covariate to measure and control. Following the same procedure as in the posttest above the reliability coefficient found was 0.79 for the pretest. Thus the claim to validity of the pretest was also based on the split-half reliability coefficient as a measure of internal consistency.

The pretest questions varied from multiple choice objective type questions to computations and problems for solution. The scoring was the same as for the posttest described earlier above.

Motivation Scale In planning and constructing the motivation scale (Appendix III), construct and concurrent criterion related validity were given the main attention. This followed upon recommendation in this regard made by Gronlund (1981). Psychological constructs and behaviors that might be predicted from theory of motivation related to mathematics learning were identified.

The researcher had then taken up temporary normal teaching of mathematics at Leopards Hill Secondary School (LHSS), Lusaka. The purpose of the temporary teaching included gaining ideas for the construction of the present draft instruments in readiness for later pilot testing of the instruments. Observations on the above identified and predicted behaviors were made at LHSS on each student of two Grade Eight classes the researcher taught there.

The behaviors observed pertained to each student's : voluntary completion of uncompleted classwork during a student's free time; handing in of homework given on time; doing extra exercises at home not suggested by the teacher;

doing extra exercises at home suggested by the teacher as being optional; keeping a good classwork mathematics record; doing corrections on work done incorrectly as marked by the teacher; regularity of attendance of mathematics lessons; and punctual readiness at the beginning of each mathematics lesson. Each behavior observation result per student was scored by the researcher on a three point scale weekly. The totals of the weekly behavior scores over a period of six weeks were ranked. Concurrently during this period draft items for the motivation scale to be pilot tested were being constructed.

In the construction of the motivation scale for the pilot tests, deliberate effort was made to conceal the face validity of the scale (Gronlund, 1981). The rationale was to avoid influencing the subjects' responses to the scale items by revealing that the students' motivation was being measured. These items were then pilot tested at the study two Matero secondary schools as indicated earlier. The objectives of the pilot study were (i) to validate the draft motivation scale through an item analysis using the test of internal consistency. (ii) Test the appropriateness of the material content and clarity of language used in the test items. (iii) Check if the Likert-type numerical scoring of the motivation scale was appropriately assigned to the options.

Internal consistency test was used on the pilot items' scores of the motivation scale as follows. If the total score (X_t) per item of the top scoring 27 percent sample subjects ($n = 69$), exceeded the total score (X_b) of the bottom scoring 27 percent on the same item by 12 or more ($(X_t - X_b) \geqslant 12$) the item was selected. The limit of 12 was chosen such that a reasonable number (about 20) of the best items could be selected. Appendix III presents the motivation scale thus created. One claim to validity of this motivation scale therefore, was that items were selected on the basis of the result of an internal consistency test. The selected items had an X_t value exceeding the X_b value by 12 or more ($(X_t - X_b) \geqslant 12$). The items were thus assumed to be more differentiating and probably therefore closer to each other in measuring the same dimension of motivation. The less differentiating items with $(X_t - X_b) < 12$ were assumed to measure different dimensions of motivation and therefore discarded.

The second claim to validity of the motivation scale arose from the following. The pilot tested motivation scale was administered, before the main study began, to the original Leopards Hill Secondary School students taught earlier by the researcher when the motivation scale was being assembled. The resulting scores were ranked. Their rank order was then correlated with the rank order of the 'behavior scores' of the same students referred to on pages 93 to 94 above. The calculated Spearman Rank Correlation found was 0.76 from the formula

$$\rho = \frac{1 - 6\sum D^2}{N(N^2 - 1)}$$ Where D = difference between ranks. N = number of subjects = 33

The value 0.76, following Bruning and Kintz (1968:191), was accepted as reasonable evidence of concurrent criterion related validity of the study motivation scale.

The motivation scale items were statements modelled on the Likert-type five point scoring scale. In scoring, each item statement was coded plus (+) or minus (-). Statements coded plus were those whose endorsement indicated favour toward learning mathematics. Statements coded minus were those whose endorsement indicated disfavour toward learning mathematics. Table 2 below shows the Likert-type five point numerical scale 5, 4, 3, 2, 1 used as a scoring guide on the plus and on the minus motivation scale items.

TABLE 2

NUMERICAL SCORING GUIDE

	STRONGLY AGREE	AGREE	UNDECIDED	DISAGREE	STRONGLY DISAGREE
PLUS ITEMS	5	4	3	2	1
MINUS ITEMS	1	2	3	4	5

<u>Attitude Scale</u> Deliberate effort was made to conceal the face validity of the attitude instrument (Appendix IV). This was intended to reduce any related possible influence that might result if the subjects became aware of what the instrument was attempting to measure. True attitudes might then not show. Following Gronlund (1981), construct and

content validity were given priority attention. Attempts were made to relate item content to selected constructs in attitude psychology regarded in the present study as being central. The constructs were those of beliefs and feelings of like and dislike related to : mathematics as a process; difficulty in learning mathematics; utility place of mathematics; and others.

While teaching at Leopards Hill Secondary school, the researcher took the opportunity to learn from views of students and teachers about mathematics during informal discussions deliberately provoked for the purpose. Ideas gained together with observations made in the interactions helped in the shaping of the draft content of the attitude scale which was then being prepared for pilot study. The pilot testing of the scale took place later at Matero Girls' and Matero Boys' secondary schools

The objectives of the pilot testing were (i) to validate the draft attitude scale through an item analysis using the test of internal consistency. (ii) Test the appropriateness of the material content and clarity of language used in the test items. (iii) Check the Likert-type numerical scoring of the attitude scale to find out if it was appropriately assigned to the options.

The test of internal consistency briefly introduced earlier on page 87, was applied to the pilot test scores of the attitude scale as follows. If the total score X_t per item of the top scoring 27 percent of the sample subjects (n = 69) exceeded the total score X_b of the bottom scoring 27 percent, on the same item, by 19 or more ($(X_t - X_b) \geq 19$) the item was selected. The limit of 19 was set up so as to enable the selection of a reasonable number (about 20) of the best test items. Appendix IV presents the study Attitude Scale thus created.

The main claim to validity of the attitude scale therefore was in the use of the criterion of internal consistency in the selection of items. The selected items with X_t exceeding X_b by 19 or more ($(X_t - X_b) \geqslant 19$) were assumed to be more differentiating and therefore more probably closer to each other in measuring the same attitude dimension. The less differentiating items with $(X_t - X_b) < 19$ were assumed, probably to measure different dimensions of attitude and were therefore discarded.

Attitude scale items were all of the five point Likert-type. Their coding into plus and minus and the method of scoring were as described on page 96 with respect to the scoring of the motivation scale.

Home Socio-Economic Status (SES) Scale In constructing the SES scale, assumptions were that the main indicators of a student's home socio-economic status, in accordance with the conceptual framework guiding the present study, were: educational qualifications, occupation and rank-in-the-job of each of the parents or a guardian; educational qualifications, occupation and rank-in-the-job of the

<u>most</u> successful brother and of the <u>most</u> successful sister; occupation of the husband of the most successful sister. The latter was in recognition of the adolescent status of siblings in an extended family set up;[5] parental provision of mathematics related environment during the sample students' pre-school life; and current parental help when a student is in difficulty with mathematics homework.[6] The construction of the home SES scale items for pilot testing were based on the foregoing indicators. The selection of the indicators also benefitted from informal discussions with some Zambian parents, teachers and students of varied socio-economic positions in life. Parents' income was deliberately omitted because of experience gained in an earlier similar study.[7] From the foregoing discussions, it became apparent that revealing incomes might not be popular with most of the parent respondents to the scale items. Also changes in the value of money, during the fifteen years over which data was sought, was thought might probably render income data less meaningful and difficult to interprete.

Pilot testing of the items took place after the initial assembling of the scale described above, at Matero Girls and Matero Boys Secondary schools as indicated earlier. The items of the student's home socio-economic status scale Appendix V , were mainly a mixture of open ended statements for completion and Likert-type multiple option choice on a continuum. The former were scored on a point marking system in the same way as described for scoring the achievement posttest scale items. The Likert-type multiple option choice items were scored in the same way described for scoring the motivation scale on page 96 above.

The objectives of the pilot test were (i) to validate the draft SES scale through an item analysis using the test of internal consistency. (ii) Test appropriateness of the material content and clarity of language used in the test items. The test of internal consistency briefly introduced on page 87 above was then applied to the pilot test scores of the SES scale as follows. If the total score X_t per item of the top scoring 27 percent exceeded the total score X_b of the bottom scoring 27 percent, on the same item, by 17 or more, $(X_t - X_b) \geqslant 17$, the item was selected. The limit 17 was chosen so as to enable selection of a reasonable number (about 12) of the best test items, but not too many to bore the parent respondents to the questionnaire. The Student's home SES scale, Appendix V, was thus created.

The main claim to validity of the SES scale was therefore in the use of the criterion of internal consistency in the selection of items. The selected items, which had X_t exceeding X_b by 17 or more, $(X_t - X_b) \geqslant 17$, were thus assumed to be more differentiating and probably therefore closer to each other in measuring the same SES dimension. The less differentiating items with $X_t - X_b < 17$ were assumed, probably to measure different dimensions of the student's home socio-economic status and were therefore discarded.

<u>Instruction</u>

Under this heading, the general objectives of the study instruction are briefly given. Then the general content and source of the selected lesson material is discussed. A rationale for the choice of this lesson material for the purpose of achieving the general objectives of the instruction is discussed next. The heuristic versus expository methods of instruction used in lesson presentations were then distinguished and a summary table of lesson titles and time durations of instruction given. The actual lesson guide outlines are in Appendix VI.

<u>General Objectives of the Study Instruction</u>. The general objectives of the study instruction were as follows. At the end of the instruction an evaluation test was to demonstrate that each student :

1.0 Knows basic terminology, definitions, notations, facts and relations concerned with the lesson materials taught.

2.0 Understands basics of logico-mathematical structures involving number, symbol and figure such as : class inclusion used in classifying objects; seriation as in ordering objects; transitivity as in, if $A > B$, $B > C$ then $A > C$; logical classification basic to some concepts in logic and mathematics thinking; topological basic structure also useful in differentiating between Euclidean Geometric Shapes.

3.0 Demonstrate skills to :

3.1 do operations on number and symbol;

3.2 identify, distinguish between or classify sets of objects;

3.3 abstract and generalise on the foregoing knowledge, understandings and skills;

4.0 Apply the foregoing knowledge, understandings, skills, abstractions and generalisations to new situations involving number, symbols, figure diagrammes, sets and Euclidean Geometric Shapes which require:

4.1 computations;

4.2 solving problems through,

4.2.1 identifying the material elements of the problem (application);

4.2.2 selecting and using appropriate skills and generalisations (application);

4.2.3 conscious knowledge of the parts of the problem and necessary forms of thinking involved (analytic);

4.2.4 original creative thinking (synthetic)

5.0 Evaluate by making judgements such as bigger or smaller, correct or wrong.

Content and Source of Lesson Material. The study lesson material consisted of excerpts from subject matter introducing (i) the Algebra of set. The materials included description of a set, membership of a set, subset, intersection of sets, universal set, complement set and Venn diagrams representing and illustrating some of the foregoing concepts and other related concepts not listed above.

(ii) Euclidean Geometry of Solid Shapes. The geometry included a study of the external characteristics and classification of the shapes. Concepts studied under the Algebra of sets were then applied to the study of the Euclidean Geometric Shapes.

The main students' text book used for the source of the lesson materials was SMG, Modern Mathematics for Schools, Book 1. London : Blackie and Sons 1971. The text book was preferred because it is widely used for the Grade Eight mathematics course in Zambia. Copies of the book were also available in the study schools.

Rationale for Choice of Study Lesson Material. The present study conceptual framework, incorporated assumptions made on the basis of common sense and other study observations concerning Zambia. Piaget's contribution (Copeland, 1974) on how children first acquire logico-mathematical knowledge was then used to impose structure on the forementioned assumptions and observations in formulating the conceptual framework. Thus Piaget's findings became important for the present study.

Piaget found the development of the number concept to be part of the child's growth. Reports on Piaget's experiments (Copeland, 1974; Isaac, 1963) suggest that the number notion evolves gradually in stages closely related to the development of ideas of serial order, the logic and mathematics of class relations and elementary concepts of space.

Number in the foregoing context, is seen as "a property of a set of objects" (Copeland, 1974:55). Experience with sets in this view, could help the child's thinking to develop some basic logico-mathematical concepts. These might include concepts of : constancy of number , that is, a number of objects in a set is independent of how the objects are arranged; logical mathematical relation of class inclusion, that is , if A includes B, and B includes C, then A includes C ; logico-mathematical relation of transitivity necessary for ordering or hierachical classification, that is, if A is greater than B, and B is greater than C, then A is greater than C ; multiple classification powerfully expressed by the Venn diagrams of intersecting sets; and so on.

The logic of class inclusion and hierachical classification in the above view, were also seen as examples of experience necessary to develop the child's capacity to abstract and generalise (Copeland, 1974). The idea of relation also helps to provide some other basic ideas in both mathematics and logic. Venn diagrams are seen as convenient and powerful tools for expressing relations.

The basic concepts in mathematics and logic discussed above, appeared to be some of the kind of foundations the Zambia Primary School Mathematics course attempts to teach. The present study population consisted of fresh primary school graduates to be initiated into the higher level of secondary school mathematics. The secondary school course needs foundations of this kind to build on. Thus the selection of lesson material from the domain of these basic logico-mathematical concepts, for the kind of population selected, was thought appropriate for the study.

Heuristic versus Expository Lesson Presentations. The actual plans of lessons taught are presented in Appendix VI. The same lesson outline, content and sequence of presentation of materials was followed in Expository and Heuristic lesson presentations except as follows.

(a) Expository lesson presentation had, at all the stages of lesson development (i) a liberal teacher input of information giving away answers. (ii) Questions not marked with an arteristic (*) in the lesson plans were posed but promptly answered by the teacher without giving the students much chance to discover answers on their own. (iii) Every effort was made to conduct the lessons according to the operational definition of expository instruction of the study in Chapter I.

(b) In the heuristic presentation on the other hand, (i) the teacher very sparingly supplied information even that containing clues. (ii) The students were given as much chance and time, as was possible, in an encouragement for the students to discover the answers or solutions with the minimum of the teacher's help. (iii) Questions marked with an asterick were reserved for the heuristic method of instruction. Every effort was made to conduct the lessons according to the operational definition of heuristic instruction given in Chapter I. Table 3 below showed a summary of the titles of lessons taught and the time allocated to the teaching of each lesson.

TABLE 3

SUMMARY OF LESSON TITLES AND TIME ALLOCATIONS

LESSON CODE	TITLE	No. OF PERIODS	DURATION (minutes)
1.1	Description of set	2	80
1.2	Membership of a set	2	80
1.3	Subset	2	80
1.4	Universal set	1	40
1.5	Venn diagrams as pictures of sets	2	80
1.6	Revision exercises on sets	1	40
2.1	Survey of solid geometric shapes	2	80
2.2	Cube and cuboid	2	80
TOTALS FOR TEACHING		14	560

Table 4 below showed school periods spent on administration of study instruments and other formalities.

TABLE 4

SUMMARY OF SCHOOL PERIODS SPENT ON
ADMINISTRATION OF INSTRUMENTS

TYPE	No. of PERIODS
Pretest on mathematics achievement	2
Posttest on mathematics achievement	2
Attitude and Motivation scales	2
Home socio-economic status scale	2
Total number of periods	8

Data Collection

Data for the content of the draft instruments in readiness for pilot studies, was finalised during the researcher's normal mathematics teaching at Leopards Hill Secondary school. This was between June 1985 and September 1985. Pilot studies were then conducted at Matero Girls and Matero Boys Secondary schools from 14 October 1985 to 29 October 1985. The main study lesson instructions and main data collection commenced from 17 February 1986 continuing to 21 March 1986.

During the normal mathematics teaching of the Grade Eight classes at Leopards Hill Secondary School (LHSS), informal discussions were deliberately provoked with students and teachers to gain ideas on what students and teachers thought of mathematics. The ideas helped the shaping of item content of the various draft pilot instruments. During the same pre-pilot period at LHSS, observations were made and scored on student behaviors thought indicative of motivation towards learning mathematics. These behavior scores were later used for a 'criterion related validation test' of the motivation scale.

<u>Pilot Data Collection.</u> Pilot trials of the instruments were administered by the researcher in person to one female grade eight class of Matero Girls Secondary school and to one male grade eight class of Matero Boys Secondary school, both in Lusaka. In the administration of the instruments, there were no other announcements made regarding the content of any of the instruments beside what appeared on the top paragraph of each instrument. The pretest was administered first followed a week later by the posttest. Thus the pretest was not preceeded by any fresh learning of the study materials while the posttest followed the 'learning' pilot students might have had from answering the pretest.

On Friday 17 October 1985, both pilot classes were given the student's home Socio-Economic Status (SES) pilot scale. The students were first asked to read through the scale carefully so as to seek clarification on any part that might not be clear. The students were then told that they were accordingly to explain to their parents anything in the scale that might not be clear. The students were further asked to take the SES pilot scale home and see to it that the parents completed the scale questionnaire in readiness to be brought back the following Monday. Those successfully carrying out this task were promised their own questionnaire to complete. This referred to the Motivation and the Attitude scales. Ninty two percent of the SES pilot scales were returned completed on Monday . The procedure of Friday to Monday completion of the SES scale was consequently adopted for use in the main study.

The motivation and the attitude scales were presented to the subjects in one questionnaire. The first half of the questionnaire consisted of the motivation scale while the rest measured attitude. Thus the students' responses to both motivation and attitude pilot scales were collected in one sitting. A total of 69 students took part after discarding all questionnaires not fully completed. At the end of the administration of the joint motivation - attitude questionnaire, the students were asked to indicate any difficulties encountered in completing the questionnaire. Points raised were considered in the final shaping of the scales for the main study.

The completed pilot study questionnaires, were serially numbered on collection for future identification as no names appeared on them. The coding and scoring of the scales was as described earlier for each scale under the heading <u>instruments</u> on page 86.

The main data were collected, using the pilot tested instruments, from the two grade eight female classes at Kabulonga Secondary School for Girls and from the two grade eight male classes at Kabulonga Secondary School for Boys. The collection of main data took place from 17 February 1986 to 21 March 1986 during the period in which the four study classes also received the study instruction in mathematics.

The pretest was administered before any of the study lessons were given. The posttest on the other hand, was administered one day after the last study lesson was given in each class. The motivation and attitude scales were administered after the posttest. The student's home socio-economic status scale was administered one week before the end of the study lessons.

The response scripts for each of the five instruments were serially numbered for identification as the scripts were being received from the respondents in each case. Scripts from the same respondent subject were given the same serial number. The coding and scoring of the responses for each scale was as described respectively for each scale under instruments subheading above.

Control of Variables

Deliberate effort was made to control expected variable effects, not being studied, as follows among other measures.

(i) Random assignment of subjects to the experimental and to the control subgroups. Randomisation of this kind was intended to randomly distribute variance due to individual differences among the sample subjects. An assumption could thus be made that the sample subjects had been equalised to allow study variables show their effects more clearly.

(ii) Covariate control was incorporated into the study design so as to be able to adjust for the covariate effects on the criterion variable.

(iii) The researcher taught all lessons and administered all instruments in person in an attempt to control related variables.

(iv) All five instruments for data collection were first validated through pilot studies as described under <u>instruments</u> on page 86.

(v) Between schools variance was controlled by reproducing the experiment in each of the study schools (Kerlinger, 1973:368). Thus each school had its own stratified selection followed by a random assignment of subjects to study classes and then a random determination of the experimental and control classes. The two study schools selected, being centrally controlled by the same Ministry of Education, probably shared much in common in matters such as school policy, curriculum, resources, administrative structures, procedures in school organisation and other factors. The choice of the two schools was partly influenced by factors inclusive of the foregoing similarities. Similarities of the kind were expected to reduce between-schhols variance

(vi) The length of the study instruction period was limited to five weeks as a measure to reduce the creeping in of the effects of some other extraneous factors. Such factors included: a possible gradual failure to mantain strict standardisation of the difference between heuristic and expository instruction by the same instructor over a long period; variation experienced in the size and composition of students in the study classes resulting from some students leaving and new ones being admitted by the schools to fill the vacant places; interference on the study program legitimately arising out of the normal scheduled operations of the term's programs of the schools. The latter included activities such as related to sporting events and end of term tests.

(vii) Data collected from students who were not randomly assigned to the original study classes was not included, in the analysis.

(viii) A register of attendance was strictly kept for each lesson, so that data from students who were present for all lessons was used in the analysis.

Data Analysis.

The Statistical Package for Social Sciences (SPSS) computer subprogram Three-way Analysis of Variance (ANOVA) and Covariance was used to analyse the main data. The sub-program fitted the analysis since the study design was multivariate consisting of a 2 x 2 x 2 Orthogonal Factorial Experiment with control over four selected covariates. The subprogram was also appropriate for the study design data intended to be simulteneously analysed to test the main and the interaction effects of the independent variables. The three-way ANOVA with covariance computer subprogram also fitted the analysis of the non-metric nominal data of the three independent variables (factors) together with the metric assumed interval data of the dependent variable, and of the four covariates controlled. The computer output of the subprogram was able to test all seven null hypotheses and their alternatives.

Two-tailed tests of significance at the 0.05 level were used to determine the acceptance or rejection of each of the seven null hypotheses. Additional data analysis was done using a desk calculator to search for more meaning to some aspects of the result of the main data analysis. Table 5 below showed the scheme of analysis used for testing the study hypotheses.

TABLE 5

SUMMARY OF DATA ANALYSIS SCHEME USED FOR HYPOTHESES TESTING .

HYPOTHESIS	DATA USED	MAIN STATISTICAL TEST USED.	OTHER SUPPORTIVE TESTS USED
Null hypothesis One	Instruction method categories: heuristic/ expository on SAM scores	F-ratio on ANOVA effects of method on SAM	t - test on category means
Null hypothesis Two	Ability categories: high /low on SAM scores	F-ratio on ANOVA effects of ability on SAM	t - test on category means.
Null hypothesis Three	Sex categories male/ female on SAM scores	F-ratio on ANOVA effects of sex on SAM	t - test on category means
Null hypothesis Four	Method and Sex categories on SAM scores	F-ratio on ANOVA interaction effect of method and sex on SAM	
Null hypothesis Five	Method and Ability categories on SAM scores	F-ratio on ANOVA interaction effects of method and ability on SAM	
Null hypothesis Six	Ability and Sex categories on SAM scores	F-ratio on ANOVA interaction effects of ability and sex on SAM	
Null hypothesis Seven	Method, ability and Sex categories on SAM scores	F-ratio on ANOVA interaction effects of method, ability and sex on SAM	

Supportive tests for Null Hypotheses One to Three are indicated in the last column. However, no supportive tests were used for Hypotheses Four to Seven. The latter null hypotheses tested interaction effects. Interaction effects appeared more complex in nature than the single factor main effects tested in Null Hypotheses One to Three. Consequently, supportive tests on the interaction effects were not carried out in order to limit the extent of the analysis of the data.

<u>Analysis of scores</u>. Under this subheading, details of the SPSS subprogramme's data inputs and corresponding outputs are outlined. Scores of the Students' Achievement in Mathematics (SAM) measuring post treatment achievement, were used as input into the SPSS computer subprogram Three-way ANOVA with Covariance to test the seven null hypotheses and their alternatives. Case frequencies in the cells were kept equal by random reductions where it became necessary, so as to have an orthogonal factorial analysis. The orthogonal element in the analysis was intended to make the calculations of the various component outputs as well as the interpretation of the results less involved (Nie et al., 1975:398-405).

The SPSS subprogram ANOVA with Covariance (Nie et al., 1975:398-433) was selected because the program appeared more appropriate to the present study objective of investigating causal effects on SAM of the study independent variables. Thus the subprogram appeared suited to the study of the non-metric factors (independent variables) instruction method, ability and sex. At the same time the subprogram appeared able to satisfy the need to control at least the more expected metric covariates of previous mathematics learning, attitude toward mathematics, motivation and student's home socio-economic status. The metric covariates were incorporated into the study design in an attempt to reduce any extraneous variation in students' achievement in mathematics they might cause. Hopefully thereby, improving precision in measurement. The effects of the non-metric independent variables however remained the primary focus of the study. Consequently Option 8 which controls the order of the analysis of the variables was used as provided by the SPSS ANOVA subprogram. This option ensured that the assessment between types of effects was in the order of firstly the non-metric factors, adjustment for these non-metric factors, then covarites followed by interaction effects (Nie et al., 1975:415). Factors under this option 8 also became automatically adjusted for all other factors. Covariates in turn became adjusted for all other covariates and factors. The interaction effects were adjusted for covariates, factors and all other interaction effects of the same and lower orders. Thus the effects within each type became adjusted for the effects of all the prior types (Nie et al., 1975:414)

Under the same subprogram, ANOVA options 9 and 10 and their default determined the approach to the assessment of effects. Default was adopted for the present study so as to obtain a Classical Experimental Approach. In this approach, each factor was adjusted for the other factors. Covariates were also adjusted for other covariates.

Subprogram ANOVA with Covariate Statistic 1 was evoked for the present study computer data analysis. Statistic 1 resulted in a Multiple Classification Analysis (MCA) output table presented in Chapter IV as Table 7. The MCA table was additional to main ANOVA summary output table of the subprogram. The MCA table was necessary to provide a further display of results beyond the mere statistics for tests of significance provided by ANOVA. Nie et al. (1975:409) further noted that the MCA table data was particularly useful where attribute variables, such as sex and ability in the present study, were involved.

The MCA table gave data which included: category means expressed as deviations from the grand mean; unadjusted category effects for each factor; category effects adjusted for other factors; category effects which had been adjusted for all factors and covariates; and Eta, Beta, and Multiple Regression (R) values.

The adjusted values in the MCA table enabled the present investigator to assess the magnitude of the remaining category effects, factor by factor as other factors or covariates effects were being partialled out. Values of Eta squared indicated the proportion of variance explained by the combined categories of each non-metric (independent variable) factor. The Beta values associated with the category effects for each factor on the MCA output table represented partial correlation ratios. These ratio values might then be seen as standardised partial regression coefficients. The Multiple R values, in the

MCA table represented multiple correlation between the dependent variable SAM and all factors (independent variables), covariates (previous mathematics learning, motivation, attitude and SES) and factor by factor interaction terms.

R^2 for the column of the MCA table in which adjustments were made for independent variables (instruction method, ability and sex) represented the proportion of variation in the dependent variable SAM explained by the additive effects of the independent variables. R^2 of the column in which adjustment had been made for independent variables and the covariates, indicated the variation in the dependent variable explained by the additive effects of all factors and covariates.

The foregoing inferences from the MCA table were however limited by the levels of interaction effects between the factors. The use of equal frequencies in the cells of the present design (orthogonal character) was also intended to keep these interaction levels low.

Notes

1. Estimate made on the basis of student enrolment in Grade Eight classes of the two schools in 1985. Data for the estimates was from interviews with the Heads of the mathematics departments of the two study schools.

2. Opinion also expressed in the Note 1 interviews.

3. Estimate made on the basis that Grade One admission is open to seven year olds officially. These should therefore turn fifteen years or nearly when in the eigth grade.

4. Republic of Zambia, Education Reform Special Investigation Report: Examinations, Evaluation and Guidance. (Lusaka: 1975).

5. The idea of including the immediate members of the extended family in evaluating a student's home socio-economic status in an African situation arose in a discussion the researcher had with Dr P.P.W. Achola of the Educational Research Bureau, University of Zambia, Lusaka in 1985.

6. The assumption here is that parents in homes of higher socio-economic status were more likely to have concern and the capacity to give such help. One basis for the assumption is that education in Zambia, as elsewhere in developing countries, tends to be an important ladder to higher socio-economic status.

7. M.W. Njobe "Effects of the Agricultural Science Curriculum, the school environment and the student's home socio-economic status on attitudes toward careers in Agricultural Production". Unpublished M.Ed Dissertation, University of Zambia, Lusaka, 1983.

CHAPTER IV

RESULTS AND DISCUSSION

The findings of the study according to the hypotheses and methodology were summarised and discussed as presented below. Tables 6 and 7 presented summary results of the main study data analysis. Table 6 summarised the result of a three-way Analysis of Variance (ANOVA) and an analysis of Covariance. Table 7 presented a Multiple Classification Analysis (MCA) table showing the pattern of effects summarised in Table 6. Table 8 presented a cross-tabulation of factor category subgroup Students' Achievement in Mathematics (SAM) mean scores according to method of instruction, ability and sex. Tables 9, 10, and 11 presented summary results of additional data analysis comprising t-test comparisons of SAM mean scores of study subgroups.

RESULTS

Results of Main Data Analysis. Table 6 below shows a summary result of main data analysis used to test null hypotheses One to Seven and their alternatives.

TABLE 6

THREE-WAY ANALYSIS OF VARIANCE AND ANALYSIS OF COVARIANCE SUMMARY DATA N = 96

	SAM	:	STUDENTS' POSTTEST ACHIEVEMENT IN MATHEMATICS
BY	METH	:	METHOD OF INSTRUCTION
	ABIL	:	ABILITY LEVELS OF STUDENTS
	SEX	:	SEX OF STUDENT
WITH	PRET	:	STUDENTS' PRETEST ACHIEVEMENT IN MATHEMATICS
	SES	:	SOCIO-ECONOMIC STATUS OF STUDENT'S HOME
	ATT	:	ATTITUDE OF STUDENT TOWARD MATHEMATICS
	MOT	:	MOTIVATION OF STUDENT TOWARD LEARNING MATHEMATICS

HYPOTHESIS	SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARE	F	SIGNIFICANCE p
	Main Effects	2006.208	3	668.736	6.555	0.001
H_o One	METH	112.667	1	112.667	1.104	0.297
H_o Two	ABIL	1820.042	1	1820.042	17.840	0.001
H_o Three	SEX	73.500	1	73.500	0.720	0.999
	Cavariates	4323.533	4	1080.883	10.595	0.001
	PRET	3004.470	1	3004.470	29.450	0.001
	SES	7.708	1	7.708	0.076	0.999
	ATT	193.087	1	193.087	1.893	0.169
	MOT	438.525	1	438.525	4.298	0.039
	2-Way Interactions	566.846	3	188.949	1.852	0.142
H_o Four	METH/SEX	456.74	1	456.741	4.477	0.035
H_o Five	METH/ABIL	86.004	1	86.004	0.843	0.999
H_o Six	ABIL/SEX	26.056	1	26.056	0.255	0.999
	3-Way Interaction	8.284	1	8.284	0.081	0.999
H_o Seven	METH/ABIL/SEX	8.284	1	8.284	0.081	0.999
	Explained Variance	6904.871	11	627.716	6.153	0.001
	Residual Variance	8569.754	84	102.021		

Table 6 above showed the summary result of analysis of data for testing null hypotheses (h_o) One to Seven and alternatives (h_1). The findings below were deduced from the result.

Null hypothesis One (h_o One). Summary data for h_o One showed $F(1, 94) = 1.104$ not significant at the level of $p = 0.05$. Consequently, h_o One that there is no difference in SAM when students are taught by either a heuristic or an expository method of instruction was accepted. Alternative hypothesis h_1 One that there was a difference in SAM when students were taught by heuristic method and when taught by an expository method of instruction was rejected. On the whole therefore, the students showed no overall significant difference in SAM when taught by heuristic and when taught by an expository method of instruction.

Null hypothesis Two (h_o Two). Summary data for h_o Two showed $F(1, 94) = 17.54$, significant at $p = 0.001$. Null hypothesis Two that there is no relationship between SAM and students' levels of ability was consequently rejected. The alternative hypothesis (h_1 Two) that there is a relationship between students' achievement in mathematics and their levels of ability was accepted. Thus on the whole, students' achievement in mathematics appeared related to students' ability.

Null hypothesis Three (h_o Three). Summary data for h_o Three showed $F(1, 94) = 0.720$ not significant at

$p=0.05$. Therefore, h_o Three that there is no relationship between SAM and sex of the student was accepted. Alternative hypothesis h_1 Three that there is a relationship between SAM and the sex of the student was rejected. Thus the study sample students, taken as a whole, showed no overall significant difference in mathematics achievement on account of the sex difference.

Null hypothesis Four (h_o Four). Summary data for h_o Four showed $F(1, 94) = 4.477$ significant at $p=0.05$. Null hypothesis h_o Four that there is no sex versus method of instruction interaction effect on SAM was therefore rejected. Alternative hypothesis h_1 Four that there is a sex versus method of instruction interaction effect on SAM was accepted instead. Apparently therefore, there was on the whole, an effect on students' achievement in mathematics due to an interaction between method of instruction and the sex variable.

Null hypothesis Five (h_o Five). Data summary corresponding to h_o Five showed $F(1, 94) = 0.843$ not significant at $p=0.05$. Null hypothesis h_o Five that there is no ability versus method of instruction interaction effect on SAM was consequently accepted. Alternative hypothesis h_1 Five that there is an ability versus method of instruction interaction effect on SAM was rejected. Thus the students' ability and instruction method, on the whole, showed no interaction effect on students' achievement in mathematics.

Null hypothesis Six (h_o Six). Summary data for h_o Six showed $F(1, 94) = 0.255$ not significant at $p = 0.05$. Thus h_o Six that there is no ability versus sex interaction effect on SAM was therefore accepted. Alternative hypothesis h_1 Six that there is an ability versus sex interaction effect on SAM was rejected. Therefore, on the whole, the study found no interaction effect on students' achievement in mathematics between sex and ability.

Null hypothesis Seven (h_o Seven). Summary data for h_o Seven showed $F(1, 94) = 0.081$ not significant at $p = 0.05$. Consequently, h_o Seven that there is no ability versus sex versus method of instruction interaction effect on SAM was accepted. Alternative hypothesis h_1 Seven that there is an ability versus sex versus method of instruction interaction effect on SAM was rejected. On the whole therefore, the study found no significant overall effect on students' achievement in mathematics due to interaction among sex, ability and instruction method.

Table 6 data on the pretest covariate showed an $F(1, 94) = 29.450$ significant at $p = 0.001$. Probably therefore the students' previous mathematics learning, measured by the pretest had a significant effect on subsequent SAM. The data for the covariate motivation (Table 6), had $F(1, 94) = 4.298$ significant at $p = 0.039$. Thus the students' motivation towards learning mathematics also appeared to have a significant effect on SAM. The covariate (Table 6) on socio-economic status of students' homes and on students' attitude toward learning mathematics showed no significant effect of either covariate on students' achievement in mathematics. Probably therefore, attitude toward mathematics and the students' home socio-economic status had no significant effects on students' achievement in mathematics.

The data in Table 6 , showed the interaction between method and sex to have had $F(1, 94) = 4.477$ significant at $p=0.035$. Thus the interaction between method and sex appeared statistically significant in the result of the present study. Probably therefore, the effects of method of instruction on students' achievement in mathematics were not uniform across the male and female categories. That is, method of instruction appeared to influence students' achievement in mathematics in such a way that boys were influenced differently from girls.

Table 6 data however, showed that the interaction effects between method and ability and between ability and sex were not statistically significant. Consequently on the whole, neither the effects of method appeared to vary from one ability category to another, nor did the ability effects vary according to sex. The three-way interaction among method of instruction, ability and sex was, on the whole, also not statistically significant according to the data in Table 6.

The Multiple Classification Analysis Table 7 below provided a further data analysis display showing the pattern of the ANOVA effects summarised in Table 6.

TABLE 7

MULTIPLE CLASSIFICATION ANALYSIS

	SAM	: STUDENTS' POSTEST ACHIEVEMENT IN MATHEMATICS
BY	METH	: METHOD OF INSTRUCTION
	ABIL	: ABILITY LEVELS OF STUDENTS
	SEX	: SEX OF STUDENT
WITH	PRET	: STUDENTS' PRETEST ACHIEVEMENT IN MATHEMATICS
	SES	: SOCIO-ECONOMIC STATUS OF STUDENT'S HOME
	ATT	: ATTITUDE OF STUDENT TOWARD MATHEMATICS
	MOT	: MOTIVATION OF STUDENT TOWARD LEARNING MATHEMATICS

GRAND MEAN 40.19

		UNADJUSTED		ADJUSTED FOR INDEPENDENT VARIABLES		ADJUSTED FOR INDEPENDENT VARIABLES AND COVARIATES	
VARIABLE/CATEGORY	N	DEVIATION	ETA	DEVIATION	BETA	DEVIATION	BETA
METHOD							
1. EXPOSITORY	48	1.08		1.08		1.87	
2. HEURISTIC	48	-1.08		-1.08		-1.87	
			0.09		0.09		0.15
ABIL							
1. LOWER	48	-4.35		-4.35		-2.07	
2. HIGHER	48	4.35		4.35		2.07	
			0.34		0.34		0.16
SEX							
1. FEMALE	48	-0.88		-0.88		-1.95	
2. MALE	48	0.88		0.88		1.95	
			0.07		0.07		0.15
MULTIPLE R SQUARED					0.130		0.409
MULTIPLE R					0.360		0.640

The summary results shown in Table 7 above were presented as below. The grand mean score for Students' Achievement in Mathematics (SAM) was shown as 40.19 . The first and second columns of the table showed that, for each of the two sample subgroups of each of the three study factors, 48 subjects participated. Thus the study factorial design achieved the criterion of having equal cell frequencies. The study factorial design therefore qualified as orthogonal. Equal cell frequencies in the design meant that each cross classification among all three factors had the same number of cases. All factor effects shown in Table 7 were therefore regarded as orthogonal. Consequently the effect of each factor was considered as being independent of the effects of the other factors. The interaction effects were also taken as being orthogonal, that is , independent of the effects of the main factors (Nie et al., 1975:398-433).

The effects of each factor in Table 7, were thus taken as expressed by the sum of the squared differences of the corresponding factor category means from the grand mean (40.19) of SAM scores. Generally therefore, the assumptions were that the greater the category mean differences in a factor, the greater the sum of the squared differences for that factor.

Column three showed SAM mean scores, for each factor before adjustments, as deviations from the grand mean. These values indicated the magnitude of the effects on SAM, due to the corresponding factor. Thus the greatest effect appeared as being that of ability. Next was the effect of method of instruction and lastly that of sex.

The deviations from the grand mean showed that the SAM mean scores corresponding to each of the three main study factors were as follows. The SAM mean score for sample students taught by expository method was above the grand sample mean, while the SAM mean score for sample students taught by heuristic method was below the grand sample mean. Thus the result of the expository instruction appeared to contribute more than the result of heuristic instruction toward the raising of the overall mean mathematics achievement (grand mean) of the entire sample. The SAM mean score for the male sample students was above the sample grand mean, while the SAM mean score for female sample students was below the sample grand mean. Thus the mean scores for the male sample students appeared, on the whole, to be higher than the mean score of the female sample students. The SAM mean score for the high ability sample students was above the grand mean of the sample, while the SAM mean score for the low ability sample students was below the grand mean score. If 'ability' meant ability to achieve well (Vernon, 1971), then this study result also provides that support.

The size of the deviations from the grand mean changed for the method factor when adjustments were made for the other two study factors and for the covariates.

On the sex factor, the deviations were more than doubled when further adjustment for covariates, after adjusting for other factors was done. On the other hand, deviations from the grand mean for the ability factor remained unchanged after adjustment for other factors, but was halved when covariates were also adjusted for.

Column four showed the eta values for each of the factors. Eta is a common correlation coefficient measuring the strength of association of each factor with the criterion variable SAM. Ability appeared to correlate distinctively higher with SAM than did the other two factors. This suggested that SAM scores could be predicted more accurately from student ability scores than method of instruction used or sex of the student.

Eta squared for each factor provided a measure of the estimate of the proportion of variance in SAM explained by the combined category effects of the factor. The eta squared for the ability factor was $(0.34)^2$ and was statistically significant since the ability effects were shown significant in Table 6 ANOVA summary result. Thus the proportion of variance in SAM explained by ability was $(0.34)^2$, or 0.1156 equivalent to about 11.6 percent. The percentages for method and sex similarly calculated came out much smaller, that is, as 0.81 and 0.49 respectively.

Considering an orthogonal factorial design, the equation for analysis of variance is :

$$SS_T = SS_A + SS_{within} \qquad (1)$$

where : SS_T = total sum of squares; SS_A = sum of squares for all main factors and for interaction effects; SS_{within} = sum of squares representing error effects and other effects not accounted for. By definition:

$$\text{Eta squared } \eta^2 = \frac{SS_A}{SS_T} \qquad (2)$$

and thus from equation (1)

$$\eta^2 = \frac{SS_T - SS_{within}}{SS_T} \qquad (3)$$

$$= 1 - \frac{SS_{within}}{SS_T}$$

The following three observations are made from equation 3.
(i) $\eta^2 = 1$ if SS_{within} is zero while at the same time there is variability (SS_A) between factor category effects.
(ii) $\eta^2 = 0$ if there is no difference between factor category effects. That is, $SS_A = 0$. The latter could imply that a factor without differences in category effects, had no effect on the criterion variable.

Applying the foregoing to Table 7 therefore, the eta value of 0.34 for ability suggested the existence of a statistically significant overall difference between SAM mean scores of students of high and students of low ability. Overall category difference of means of SAM scores for students taught by heuristic and students taught by expository instruction were however not significant (Eta = 0.09). Similary, overall category mean SAM difference of male and of female students was not significant (Eta = 0.07). The significance and non-significance of these eta values is indicated by the ANOVA significance tests data on corresponding factors in Table 6.

The three factor effects of the present study are orthogonal to each other. Consequently, the algebraic sum of the squares of corresponding regression coefficients (eta or beta values) for the three factors give the proportion of variation in SAM jointly explained by the factors. However the same value of the proportion in the present study, is also given by Multiple R squared (R^2) discussed in this study later.

Columns five and six, display data on the three study factors after the effects of each factor had been adjusted for the effects of the other two factors. A beta coefficient is associated with the category effects indicated by deviations from the grand mean for each factor. Beta coefficients represent partial correlations between the criterion variable (SAM) and the respective factors. Beta and eta coefficients might be distinguished from each other as follows. An eta coefficient is equivalent to a simple beta of a bivariate linear regression of a criterion variable on a corresponding factor. In an orthogonal factorial design of the present kind, beta values are associated with sets of adjusted category effects. Beta values may be viewed as standardised partial regression coefficients.

If the partial regression coefficients of the present study trivariate design were B_1 (method), B_2 (ability), and B_3 (sex), then the relationship of the factors (independent variables) to the predicted SAM (criterion variable) score Y_1 could be expressed by the equation:

$$Y_1 = A + B_1X_1 + B_2X_2 + B_3X_3 \qquad (4)$$

where

X_1 , X_2 and X_3 represent the independent variables (factors) method, ability and sex respectively. A is the Y_1 intercept which is the value of Y_1 when

$$X_1 = X_2 = X_3 = 0.$$

That is, the predicted estimate SAM score when the three factors X_1 , X_2 and X_3 contribute zero effect to the predicted SAM score. A zero effect could mean the sum of squares associated with the regression equation line were zero. Consequently, the predicted score would be the mean. That is, the grand mean of the study sample SAM scores given by :

$$Y_1 = A = 40.19 \qquad (5)$$

From equation 4, it follows that if the value of Y_1 changed from Y_{1a} to Y_{1b} due to corresponding changes in X_1 from X_{1a} to X_{1b}, X_{2a} to X_{2b}, and X_{3a} to X_{3b}

then from equation 4 we have :

$$Y_{1a} - Y_{1b} = B_1(X_{1a} - X_{1b}) + B_2(X_{2a} - X_{2b}) + B_3(X_{3a} - X_{3b}). \qquad (6)$$

If now,

$$X_{1a} - X_{1b} = 1$$

when

$$(X_{2a} - X_{2b}) = (X_{3a} - X_{3b}) = 0$$

then

$$(Y_{1a} - Y_{1b}) = B_1 .$$

That is, B_1 could be described as the expected change in Y_1 (SAM score) when unit change in X_1 is effected while X_2 and X_3 are kept constant. B_1 therefore indicates the difference that might be expected on SAM scores (Y) between category groups differing by one unit in X_1 while remaining equal on X_2 and X_3 effects.

Similarly for:

$$X_{2a} - X_{2b} = 1$$

when

$$(X_{1a} - X_{1b}) = (X_{3a} - X_{3b}) = 0$$

then

$$Y_{1a} - Y_{1b} = B_2 .$$

That is, B_2 indicates expected change in Y_1 for unit change in X_2 when X_1 and X_3 are kept constant.

In the same way,

$$Y_{1a} - Y_{1b} = B_3$$

when

$$X_{3a} - X_{3b} = 1$$

while

$$(X_{1a} - X_{1b}) = (X_{2a} - X_{2b}) = 0$$

Thus B_3 indicates expected change in Y_1 (SAM score) when unit change in X_3 is effected while X_2 and X_1 are kept constant.

The foregoing mathematical presentation on the regression coefficients B_1 , B_2 and B_3 could help illustrate more the meaning of the eta and the beta values in Table 7 as follows: Since B_1 and X_1 relate to method, B_2 and X_2 to ability and B_3 and X_3 to sex; and Table 7 data showed that before and after adjustment for independent variables (factors), the regression coefficients' (eta and beta) values remained unchanged as $B_1 = 0.09$, $B_2 = 0.34$ and $B_3 = 0.07$; then the following could probably be said of the factor effects before and after adjustment for each other. $B_2 = 0.34$ suggested that ability (X_2) factor could be expected to show the largest difference in predicted SAM scores between ability category groups differing by one unit while being the same in the other two factors, when compared to any of the other two factors similarly considered.

The present study factorial design is orthogonal since it has equal cell frequencies. That is, the number of subjects participating at each of the two levels of each of the three study factors was the same ($n = 48$, Table 7). Consequently, the combined effects indicated by the beta values B_1 , B_2 and B_3 are additive. This implies that in the change equation 6, if

$$(X_{1a} - X_{1b}) = (X_{2a} - X_{2b}) = (X_{3a} - X_{3b}) = 1$$

then

$$Y_{1a} - Y_{1b} = B_1 + B_2 + B_3 \qquad (7)$$

That is, the expected difference in Y_1 between two groups which differ by one unit on each of the factors X_1, X_2 and X_3 would be equal to $B_1 + B_2 + B_3$. In the context of the present study therefore, the expected difference in SAM scores between two groups which differ by one unit on each of the study factors would be

$$0.09 + 0.34 + 0.07 = 0.40 \qquad 0.57$$

for Table 7 unadjusted eta values or for the beta values after adjustment.

Columns seven and eight respectively showed the deviations and the beta values for the respective factors after the effect of each factor had been adjusted for the effects of the covariates. The deviation and the beta values for method and for sex showed slight increases over corresponding values in columns four and six. Probably therefore, the effects of method and sex shown in columns four and six had been, on the whole, adversely affected by the effects of the covariates partialled out in column eight. Thus column eight data showed that in the absence of the study covariates, students' achievement in mathematics regressed more on method and on sex.

On the other hand, the deviation and the beta values for ability decreased from columns six to column eight. Consequently, one suggestion might be that the effects of the covariates had, on the whole, reinforced the effect of ability on students' achievement in mathematics. Thus the mathematics achievement of the students apparently, tended to regress less on ability in the absence of these covariate effects.

The change in the strength of the regression of Students' Achievement in Mathematics (SAM), represented by Y_1, on method (X_1), ability (X_2) and sex (X_3) from before to after partialling out the effects of the covariates could be illustrated as follows.

Considering that:

$$Y_1 = A + B_1X_1 + B_2X_2 + B_3X_3$$

then since from equation 5,

$$A = 40.19$$

the regression equation for SAM before and after taking out the effects of the covariates could be written respectively as:

$$Y_{1\ before} = 40.19 + 0.09X_1 + 0.34X_2 + 0.07X_3 \qquad (8)$$

$$Y_{1\ after} = 40.19 + 0.15X_1 + 0.16X_2 + 0.15X_3 \qquad (9)$$

Applying expected difference equation 7, then

$$Y_{1\ after} - Y_{1\ before} = (0.15 + 0.16 + 0.15) - (0.09 + 0.34 + 0.07)$$

$$= 0.46 - 0.50$$

$$= -0.04$$

which is negative.

Thus the partialling out of the effects of covariates appeared to decrease the expected difference in criterion variable (SAM) scores (Y) between two groups which differed by one unit on each of the three factors X_1, (method), X_2 (ability) and X_3 (sex). That is, in the present study, the taking out of the effects of the covariates previous mathematics learning, socio-economic status of student's home, attitude toward mathematics and motivation towards learning mathematics appeared to have an overall effect of decreasing the joint effect of method of instruction, ability and sex on students achievement in mathematics.

The bottom of Table 7 recorded values of 'multiple R ' and 'multiple R squared'. Multiple R represented the multiple-correlation coefficient between the criterion variable SAM and the three study factors taken jointly. The R value gave indication of the degree to which the three factors taken together jointly predicted SAM scores. R = 0.360 at the bottom of column six showed that the combination of method, ability and sex appeared more correlated with SAM than either method or ability or sex taken alone - as judged from the eta values in column six.

The multiple R value increased from 0.360 in column six to 0.640 in column eight where the effects of the covariates had been taken out. The increase suggested that the multiple correlation between the study criterion variable and the independent variables (factors) apparently increased as the effects of the covariates were partialled out. Probably therefore, SAM scores could be more accurately predicted from the combination of the predictors method, ability and sex than from anyone of these predictors taken singly. The power of prediction of SAM scores from the combination of method, ability and sex appeared therefore to increase when the effects of previous mathematics learning, students' home socio-economic status, attitude toward mathematics and motivation toward learning mathematics are taken out.

Since the study factorial design is orthogonal, the multiple R squared value of 0.130 at the bottom of column six, indicated the corresponding proportion of variance in SAM explained by the additive effects of method, ability and sex after adjusting the effects of each factor for the effects of the other two factors. Similarly multiple R squared value of 0.409 at the bottom of column eight, represented the proportion of variance explained after adjustments for factors and covariates. Thus the explained variance appeared to increase from 13 percent (0.130) in column six to about 41 percent (0.409) in column eight after adjusting for covariates. Apparently therefore the taking out of the effects of covariates tended to raise the proportion of explained variance from 13 to about 41 percent.

Variance not explained might include error variance and variance due to variables not taken care of in the study design.

<u>Results of Additional Data Analysis</u>. Tables 8, 9, 10 and 11 presented the summary result of additional data analysis done in a search for more meaning to some aspects of the main data analysis result. Table 8 below summarised in a cross tabulation of factor category subgroup mean scores of Students' Achievement in Mathematics (SAM) according to each of the study factor levels.

TABLE 8

CROSS-TABULATION OF FACTOR CATEGORY SUBGROUP SAM MEAN SCORES ACCORDING TO METHOD OF INSTRUCTION, ABILITY, SEX.
N=96

	MALE SUBGROUPS SAM MEAN SCORES		FEMALE SUBGROUPS SAM MEAN SCORES	
	HIGHER ABILITY	LOWER ABILITY	HIGHER ABILITY	LOWER ABILITY
HEURISTIC INSTRUCTION	49.83	33.5	37.67	35.42
EXPOSITORY INSTRUCTION	45.75	35.17	44.92	39.25
OVERALL FOR BOTH METHODS	47.79	34.33	41.29	37.33

Table 8 above presented a cross-tabulation of SAM mean scores of the study basic subgroups according to method of instruction, ability and sex factors. High ability male students' subgroups showed the highest mean scores of all the study subgroups of either sex, instructed by either method. The low ability male student subgroups on the other hand, showed the lowest means scores of all subgroups of either sex, instructed by either method. Thus female subgroup mean scores appeared sandwiched between the mean scores of the high ability male subgroups and the mean scores of the low ability male subgroups. The female subgroups, among themselves, showed that the higher ability subgroups, under either method of instruction, scored higher than the lower ability subgroups of both sexes under corresponding methods of instruction.

Table 9 below presented a summary result of subgroup t - test comparisons of the effects of the students' ability on Students' Achievement in Mathematics (SAM) mean scores.

SUMMARY RESULT OF ADDITIONAL DATA ANALYSIS: t-TEST COMPARISONS OF EFFECTS OF STUDENTS' ABILITY ON SUBGROUP SAM MEAN SCORES. N = 96

VARIABLE EFFECT COMPARED	SAMPLE SUBGROUP COMPARED	NUMBER OF STUDENTS	SUBGROUP SAM MEAN SCORE	RANGE OF SUBGROUP SAM SCORES	STANDARD DEVIATION	STANDARD ERROR OF MEAN	t-RATIO
Ability in male students irrespective of method of instruction	Male high ability subgroup taught by either of both methods of instruction	24	47.79	47	12.37	2.53	4.78, df = 46 significant at p=0.001
	Male low ability subgroup taught by either of both methods of instruction	24	34.33	27	6.11	1.25	
Ability in female students irrespective of methods of instruction	Female high ability subgroup taught by either of both methods of instruction	24	41.29	54	17.399	3.55	0.9998, df = 46 not significant at p=0.05 level.
	Female low ability subgroup taught by either of both methods of instruction.	24	37.33	30	8.589	1.75	
Ability in male subgroups taught by heuristic method	Male high ability subgroup taught by heuristic method	12	49.83	46	13.07	3.77	3.97, df = 22 significant at p=0.01
	Male low ability subgroup taught by heuristic method	12	33.50	21	5.65	1.63	
Ability in male subgroups taught by expository method.	Male high ability subgroup taught by expository method	12	45.75	33	11.84	3.42	2.696, df = 22 significant at p=0.05
	Male low ability subgroup taught by expository method	12	35.17	25	6.69	1.93	
Ability in female subgroups taught by heuristic method.	Female high ability subgroup taught by heuristic method	12	37.67	45	13.08	3.77	0.479, df = 22 not significant at p=0.05 level.
	Female low ability subgroup taught by heuristic method.	12	35.42	28	9.71	2.80	
Ability in female subgroups taught by expository method.	Female high ability subgroup taught by expository method	12	44.92	58	20.82	6.01	0.893, df = 22 not significant at ~~study~~ p=0.05
	Female low ability subgroup taught by expository method	12	39.25	24	7.21	2.08	

Table 9 above suggested the following observations.
(i) The SAM mean score of the study sample high ability male students (n = 24) taken together was significantly higher than the sample SAM mean score of the low ability male students (n = 24) of the study sample taken together ($t = 4.78$, $df = 46$ significant at $p = 0.001$). Thus taken as a whole, irrespective of method of instruction, high ability male students scored, on the whole, significantly higher than low ability male students. That is, on the whole, the ability factor appeared to influence SAM score significantly among the male students.
(ii) The SAM mean score of the study sample high ability female students (n = 24) taken together did not differ significantly from the SAM mean score of the study sample low ability female students (n = 24) taken together. Apparently therefore, taken as a whole, irrespective of method of instruction, high ability female students taken together did not, on the whole, significantly score differently from female students of low ability taken together. That is, there was no observed significant effect on SAM attributable to the ability factor among the female students taken as a whole. Thus the ability factor did not appear to have had a significant influence on SAM among the female students of the study sample. Probably therefore, the ability factor had its greatest and significant effect on SAM among the male than among the female students.

(iii) Significant differences, in subgroup means, attributable to differences in ability between : the male subgroups of high and of low ability taught by heuristic method of instruction ($t = 3.97$, $df = 22$ significant at $p=0.01$) ; the male subgroups of high and of low ability taught by expository method of instruction ($t = 2.696$, $df = 22$ significant at $p=0.05$). That is, high ability male students scored significantly higher than the low ability male students whether taught by heuristic or taught by expository method of instruction.

(iv) No significant differences, in subgroup SAM mean scores attributable to difference in ability, were apparent between: the female subgroups of high and of low ability taught by heuristic method of instruction; the female subgroups of high and of low ability taught by expository method of instruction. That is , high ability female students did not appear to score differently from low ability female students whether taught by heuristic or taught by expository method of instruction.

Table 10 below summarised the resultsof additional data analysis consisting of subgroups t - test comparisons of the effects of sex on sample students' achievement in mathematics (SAM) mean scores.

SUMMARY RESULTS OF ADDITIONAL DATA ANALYSIS: t-TEST COMPARISONS OF THE EFFECTS OF THE STUDENT'S SEX ON SUBGROUP SAM MEAN SCORES N = 96

VARIABLE EFFECT COMPARED	SAMPLE SUBGROUP COMPARED	NUMBER OF STUDENTS	SUBGROUP SAM MEAN SCORE	RANGE OF SUBGROUP SAM SCORES	STANDARD DEVIATION	STANDARD ERROR OF MEAN	t-RATIO
Sex in high ability subgroups irrespective of instruction method.	Male high ability subgroup taught by either of both methods of instruction	24	47.79	47	12.37	2.53	1.49, df=46 not significant at study p=0.05
	Female high ability subgroup taught by either of both methods of instruction.	24	41.295	58	17.39	3.55	
Sex in low ability subgroups irrespective of isntruction method.	Male low ability subgroup taught by either of both methods of instruction.	24	34.33	27	6.11	1.25	1.399, df=46. Not significantt at study p=0.05 level.
	Female low ability subgroup taught by either of both methods of instruction.	24	37.33	30	8.59	1.75	
Sex in high ability subgroups taught by heuristic.	Male high ability subgroup taught by heuristic method.	12	49.83	46	13.07	3.77	2.28, df=22 significant at p=0.05
	Female high ability subgroup taught by heuristic method.	12	37.67	45	13.08	3.77	
Sex in high ability subgroups taught by expository method.	Male high ability subgroup taught by expository method.	12	45.75	33	11.84	3.42	0.120, df=22 not significant at p=0.05
	Female high ability subgroup taught by expository method.	12	44.92	58	20.82	6.01	
Sex in low ability subgroups taught by heuristic method.	Male low ability subgroup taught by heuristic method	12	33.50	21	5.65	1.63	0.593, df=22 not significant at p=0.05
	Female low ability subgroup taught by heuristic method.	12	35.42	28	9.71	2.80	
Sex in low ability subgroups taught by expository.	Male low ability subgroup taught by expository method.	12	35.17	25	6.69	1.93	1.44, df=22 not significant at p=0.05
	Female low ability subgroup taught by expository method.	12	39.25	24	7.21	2.08	

Table 10 above, showed the following:

(i) A significant difference, in subgroup SAM mean scores, attributable to difference in sex, between high ability male subgroup and high ability female subgroup taught by heuristic method of instruction ($t = 2.28$, $df = 22$ significant at $p = 0.05$). Thus high ability male students scored significantly higher than high ability female students when both were taught by the heuristic method of instruction.

(ii) No significant differences, in subgroup SAM mean scores, attributable to sex differences between : high ability male subgroup and high ability female subgroup taught by expository method of instruction; low ability male subgroup and low ability female subgroup taught by expository method of instruction. Thus neither the high nor the low ability male subgroups appeared to score differently from the corresponding high and the low ability female subgroups under expository instruction. Probably therefore, male and the female subgroups of matched ability levels did not score differently when taught by the expository method of instruction. But under heuristic instruction, the high ability male subgroup appeared to score better than the high ability female subgroup.

(iii) No significant SAM mean differences were found between score of : male high ability students ($n = 24$) and female high ability students ($n = 24$) taken overall irrespective of method of instruction; male low ability students (n = 24) and female low ability students (n = 24) taken overall irrespective of method of instruction. Thus on the overall, irrespective of the method of instruction, no significant differences appeared between corresponding SAM mean scores of the high and of the low, male and the female student subgroups respectively. Thus the sex factor showed no overall significant effect on students' achievement in mathematics (SAM). This t-test result confirmed the main study data analysis finding in this regard.

Table 11 below summarised the result of additional data analysis comprising subgroups *t*-test comparisons of the effects of the study methods of instruction on Students' Achievement in Mathematics (SAM) mean scores.

SUMMARY RESULT OF ADDITIONAL DATA ANALYSIS: t-TEST COMPARISONS OF EFFECTS OF METHOD OF INSTRUCTION ON SUBGROUP SAM MEAN SCORES. N = 96.

VARIABLE EFFECT COMPARED.	SAMPLE SUBGROUP COMPARED.	NUMBER OF STUDENTS.	SUBGROUP SAM MEAN SCORE.	RANGE OF SUBGROUP SAM SCORES.	STANDARD DEVIATION.	STANDARD ERROR OF MEAN.	t-RATIO.
Method of instruction on male students.	Male subgroup taught by heuristic method irrespective of ability.	24	41.67	49	12.90	2.63	0.122, df=46 not significant at p=0.05
	Male subgroup taught by expository method of irrespective of ability.	24	40.46	41	10.85	2.21	
Method of instruction on female students.	Female subgroup taught by heuristic method irrespective of ability.	24	36.54	46	11.31	2.31	1.413, df=46 not significant at p=0.05
	Female subgroup taught by expository method irrespective of abli ability.	24	42.08	58	15.51	3.17	
Method of instruction on high ability male students.	Male high ability subgroup taught by heuristic method.	12	49.83	46	13.07	3.77	0.80, df=22 not significant at p=0.05
	Male high ability subgroup taught by expository method.	12	45.75	33	11.84	3.42	
Method of instruction on low ability. male students.	Male low ability subgroup taught by heuristic method.	12	33.5	21	5.65	1.63	0.66, df=22 not signifiaant at p=0.05
	Male low ability subgroup taught by expository method.	12	35.17	25	6.69	1.93	
Method of instruction on high ability female students.	Female high ability subgroup taught by heuristic method.	12	37.67	45	13.08	3.77	1.02, df=22 not significant at p=0.05
	Female high ability subgroup taught by expository method.	12	44.92	58	20.82	6.01	
Method of instruction on low ability female students.	Female low ability subgroup taught by heuristic method.	12	35.42	28	9.71	2.80	1.097, df=22 not significant at p=0.05
	Female low ability subgroup taught by expository method.	12	39.25	24	7.21	2.08	

Table 11 above showed no significant differences, in subgroup SAM mean scores attributable to difference in method of instruction, between : the high ability male subgroups taught by heuristic and by expository method of instruction; the female high ability subgroups taught by heuristic and by expository methods of instruction; the low ability male subgroups taught by heuristic and by expository methods of instruction; and the low ability female subgroups taught by heuristic and by expository method of instruction. Thus method of instruction did not appear to have any statistically significant differential effect on students of either level of ability in either sex.

DISCUSSION

Introduction The results presented above were analysed as follows. The analysis was prefaced by a summary recount of the main findings of the study. The main findings on the ability, sex and method of instruction factors were analysed next. Then followed the analysis of the main factor interactions with special focus on the statistically significant method and sex interaction. Covariate effects of previous mathematics learning measured by a pretest, students' motivation towads learning mathematics and other covariates were then analysed. An effort was made in all the analyses to relate the findings to the literature reviewed. Generalisations, conclusions, recommendations and suggestions were made for further study.

The Study. The study investigated the effects of the independent variables (factors) method of instruction, ability and sex on the dependent (criterion) variable Students' Achievement in Mathematics (SAM). The study population consisted of the 1986 Grade Eight intake of Kabulonga Secondary School for Boys and Kabulonga Secondary School for Girls in Lusaka, Zambia. The study sample (N = 96) was drawn by stratified random sampling.

The study design was an orthogonal Factorial Experiment incorporating control over some selected covariates regarded as most important. The covariate effects controlled were those of: previous mathematics learning measured by a pretest; student's home socio-economic status; students' attitudes towards mathematics; and students' motivation towards learning mathematics. The study main data were analysed with the aid of a computer. The computer sub-program three-way Analysis of Variance (ANOVA) with Covariance provided by the Statistical Package for Social Sciences (SPSS) was used for the main data analysis.

Findings. The study found that the main effects of the ability factor had $F(1, 94) = 17.240$ significant at $p=0.001$. The main effects of method and of sex factors were not statistically significant. The effects of the covariate 'previous mathematics learning' had $F(1, 94) = 29.450$ significant at $p=0.001$. The effects of covariate 'motivation towards learning mathematics' had $F(1, 94) =$

4.298 significant at p=0.39. Effects of covariates socio-economic status of student's home' and 'attitude toward mathematics' were not statistically significant. The study result also showed n interaction effect between method and sex with an F(1, 94) =4.477 significant at p=0.035. Interactions between method and ability, ability and sex, and among method ability and sex were not statistically significant at the study p=0.05 level.

Ability. There are various definitions of ability. Vernon (1971) included 'capacity to learn' as one of the suggested definitions. The present study defined ability as the student's capacity to achieve in the Zambia National Grade Seven Composite Selection Examination. Thus the study sample subjects were categorised into high and low ability groups according to the subjects' aggregate scores in the 1985 Grade Seven Composite Selection Examination. These aggregate scores, summed up the candidates' performances in six equally weighted test papers in English, social studies, mathematics, science, verbal and non-verbal reasoning.

The present study found an overall statistically significant relationship between students' achievement in mathematics and students' ability. High ability students achieved more than low ability students irrespective of sex or method of instruction. Probably, high ability students tended to: use better learning methods; assimilate learning matter more successfully; be more articulate in answering questions; and so on when compared to low ability students. Advantages identified above might then enable high ability students to achieve better than low ability students. The finding is more in accord with the common sense expectation that high ability students should achieve better than low ability students. The finding supports the definition, implicit in the observation by Vernon (1971), of ability as capacity to achieve well.

Table 17 below showed the result of additional data analysis consisting of a Spearman Rank Order comparison (Cohen, 1976) of the SAM and the ability (Grade Seven Aggregate mean scores) of the study eight basic subgroups.

TABLE 12

SPEARMAN RANK-ORDER CORRELATION BETWEEN SAM AND ABILITY MEAN SCORES OF SAMPLE SUBGROUPS

SUBGROUP DESCRIPTION	ABILITY MEAN SCORE	RANK-ORDER	SUBGROUP n	SAM MEAN SCORE	RANK ORDER
Male high ability taught by heuristic	752.58	2	12	49.83	1
Male high ability taught by expository	756.58	1	12	45.75	2
Female high ability taught by expository	729.25	3	12	44.92	3
Female low ability taught by expository	656.75	7	12	39.25	4
Female high ability taught by heuristic	729.08	4	12	37.67	5
Female low ability taught by heuristic	656.17	8	12	35.42	7
Male low ability taught by expository	672.83	5.5	12	35.17	8
Male low ability taught by heuristic	672.83	5.5	12	35.5	6

Spearman Rank-order Correlation coefficient from

$$\text{rho} = 1 - \frac{6\sum D^2}{N(N^2-1)} = 0.70$$

Using t-test (Cohen 1976) for significance

$$t = \text{rho}\sqrt{\frac{N-2}{1-\text{rho}^2}}$$

where N = 8. The t = 2.469 significant at $p = 0.05$

Table 12 above showed the rank-orders of the SAM and the ability mean scores of the study basic subgroups. The subgroups are basic in that, they were combined four at a time in various ways to constitute the main study factor categories reported upon in the ANOVA summary in Table 6.

The last two columns of Table 12, showed that for all the subgroups considered together,the high ability male subgroups ranked highest. The low ability male subgroups ranked lowest. The female subgroups ranked in between. In a way therefore, the ranks of the male and of the female subgroups SAM means scores mingled.

Though high ability male subgroup mean scores ranked higher than the corresponding high ability female subgroups SAM mean scores, every female subgroup SAM mean score appeared higher than every low ability male subgroup SAM mean score. That is, not only did every high ability female subgroup appear to score higher than every low ability male subgroup irrespective of method of instruction, but low ability female subgroups appeared to score higher than every low ability male subgroup irrespective of method of instruction. However, the differences among the foregoing subgroup means were not always statistically significant as reported earlier in Table 9.

The means of the aggregate scores (ability) Table 12 of the subgroups at the Zambia National Grade Seven

Composite Selection examination were included in Table 12 for comparison. The Grade Seven selection scores were used in the present study as 'ability' scores for categorising the sample subjects. Columns 2 and 3 in Table 12 showed respectively the Grade Seven selection mean scores and their rank order. The Spearman rank-correlation coefficient between the rank orders (Table 12) of the SAM and the ability mean scores was 0.71, df = 6 . The significance of this value was tested using t-test $t = rho\sqrt{\frac{N-1}{1-(rho)^2}}$ where :

N is the number of means ranked; and rho is the Pearson Rank-order correlation coefficient. The value of t obtained was 2.469 df = 6 significant at p=0.05 . However since N was less than 10, the above significance test might have had limitations (Bruning and Kintz, 1968:156-159). Never-the-less, there was probably a significant correlation between the subgroups' ability categorising mean scores and the study SAM mean scores of the same subgroups. That is, students categorised as high ability tended to have higher mean scores than students categorised as low ability. Again this finding confirms the main study finding in Table 6 that ability had a significant effect on SAM.

From the eta values (Table 7) ability also appeared to correlate distinctly higher with SAM compared to the method and the sex factors. This suggested that SAM might be predicted more accurately from the students' ability scores than from method of instruction used or from the sex of the student. If however the influence of covariates - on the regression effects represented by the eta and beta values in Table 7 - were also considered, the effects of ability on SAM appeared, on the whole, to have been re-inforced by the effects of the covariates. Perhaps the more dominant effects of such covariates were due to previous mathematics learning and motivation towards learning mathematics. This might be the case since the latter two covariates had significant effects on SAM (Table 6). Consequently, SAM appeared to regress less on ability in the absence of the covariate effects.

In general therefore, the results seem to suggest that ability as measured by the present Zambia National Grade Seven Composite Selection examination might be a significant predictor of students' performance in the junior secondary school mathematics. The predictive power of the ability factor however, appeared enhanced by the students' previous mathematics learning and students' motivation towards learning mathematics. This generalisation, if valid, might then be supportive of earlier findings by Ming (1975) and Sharma (1974).

Ming (1975) found the non-verbal reasoning test at the Grade Seven Composite examination to be a "useful and *valid predictor" of students performance in secondary* school technical courses. Sharma (1974), in a related study tested students in Grade Nine and found that the students' mathematics achievement was correlated weakly ($r = 0.460$) with their Arithmetic scores in the 1972 Grade Seven Composite selection examination.

Sharma complained of the low correlation and concluded that there "seems to be a dissonance" between the primar and secondary stages of Zambian education. Perhaps Sharma's dissonance might be partly linked to students' deficiency in the primary school mastery of basic logico-mathematical structures and skills necessary for a coherent continuation of performance from the primary to the secondary school mathematics course. Where previ students learning experiences left gaps in the mastery of some basic concepts and skills then students' later performances might tend to appear erratic, less correlated or random in nature and thus difficult to predict. Thus previous mathematics learning becomes a material factor on future achievement.

The present researcher's experience during the prese-ntation of the study lessons included, often observatio of sample subjects' difficulty with basic mental multiplications tables and division sums. Kasanda (1985 also found similar problems with his Winscosin eigth grade subjects. It is students' problems of this kind that might be seen as creating gaps in students' previous learning, with adverse effects on future learning.

However, unlike the Ming (1975) and the Sharma (1974) studies, the present study was not focussed on correlations between secondary and grade seven performances in part component papers of the composite examination. The present study only found that, on the whole, ability measured by the aggregate performance at the 1985 Grade Seven Composite Selection examination was a significant factor in the students' achievement in mathematics on beginning the Zambia Grade Eight mathematics course.

In an additional data analysis, a comparison of the performances of the high versus low ability basic subgroups of the study sample in each sex showed that, the male students' high ability subgroups (Table 8) had the highest SAM mean scores compared to all other subgroups. This observation might be partly explained in terms of the results in Table 1 page 65 showing that, the mean ability (Grade Seven Aggregate score) of the male high ability subgroup was significantly higher than the mean ability score of each of the other subgroups. But also notable, female students categorised as low ability and having significantly lower ability (Grade Seven Aggregate mean score) than the corresponding low ability male subgroup ($t = 50.06$, $df = 46$ significant at $p=0.001$) had a higher SAM mean score than the male low ability subgroup, even though the difference was not statistically significant.

Further investigation of the finding might be necessary. One possibility might be that the observation also probably suggested that ability was not the sole determining factor of SAM. The effects of other factors could also probably be at play. The present study, in this regard, did find statistically significant effects on SAM accountable for by: an interaction between method of instruction and sex; covariate previous mathematics learning; and covariate motivation towards learning mathematics.

Additional data analysis result of t-test comparisons of SAM mean scores of the study basic subgroups on the ability factor, were summarised in Table 9 on page 124.

The result showed that, on the whole, high ability male students scored significantly higher than low ability male students when taught by the heuristic and when taught by the expository method of instruction. However, though high ability female students also scored higher, on the whole, than low ability female students when taught by the heuristic and when taught by the expository method of instruction, the differences in the female subgroup SAM means under either method of instruction were not statistically significant. Probably therefore, the ability factor, on the whole, had a more significant effect on SAM among the male than among the female students.

The findings on ability measured by aggregate scores in the Zambia National Grade Seven Composite Selection examination might be generalised as follows. Ability had a significant effect on students' junior secondary school achievement in mathematics. This ability appeared to be a better predictor of the students' achievement in mathematics compared to method of instruction and the sex of the student.

A significant interaction effect between two factors implies that the effects of the one factor are not uniform over category subgroups of the other factor. Nie et al. (1975:403) commented that, where an interaction is significant the importance of testing significance of main effects of the interacting factors becomes less "compelling." But where the interaction is not significant, the comment went on, testing for main effects becomes worth the while. Probably therefore, in the present study, the significant interaction effect found between method and sex, might have reduced any observable overall main effects of method and of sex that might have been possible to observe on SAM. Thus , only ability - not involved in any interaction effect - of the three study factors showed a significant main effect on SAM.

That ability did not appear to interact with sex could mean that the effects of either of the factors (ability and sex) were uniform over the category subgoups of the other factor. Similarly for the other non-significant interactions between ability versus method and among method versus ability versus sex.

However the effect of ability on students' achievement in mathematics (SAM) appeared to be reinforced by effects of covariates which include previous mathematics learning and students' motivation towards learning mathematics. In the absence of the effects of the covariates, SAM appeared to regress less on ability. Probably, ability also did not significantly interact with either method of instruction or sex of the student or both to produce an effect on students' achievement in mathematics.

Comparisons of performance of the present study sample basic subgroups also suggested that high ability male students achieved better in mathematics than : the low ability male; high ability female; and the low ability female subgroups. This finding appeared to be the case whether these subgroups were taught by the heuristic or by the expository method (Table 9). However, considering the performance of female subgroups from an additional analysis of data, high ability female students achieved better than low ability male subgroups whether taught by the heuristic or the expository method. But low ability female subgroups achieved better than low ability male subgroups irrespective of whether taught by heuristic or by the expository method. However, the differences in the means compared were not statistically significant. Further study on the relative achievement of the low ability female and low ability male students appeared necessary.

The foregoing findings from additional data analysis of subgroup SAM mean score comparisons, are interesting. One point of interest was in the contrast of the two following observations. One observation was that high ability males scored better in mathematics than high ability females. This was understandable since the high ability males had higher ability (Grade Seven Aggregate scores) than the high ability females.

The second contrasting observation was that low ability females scored better in mathematics than low ability males. Yet, these low ability female students had significantly lower ability (Grade Seven Aggregate scores) than low ability males. Consequently, one possible suggestion might be that though the overall ability effect on SAM was statistically significant, at the level of subgroups performances however, other variables showed more significant effects. Some of these variables may include a method versus sex interaction found in the present study to have a significant effect on students' achievement in mathematics. Covariates which also appeared to influence the regression of students' achievement on ability, included previous mathematics learning and motivation towards learning mathematics.

Thus ability measured by the Zambia National Grade Seven Examination, probably predicts students' performance in the Junior Secondary School mathematics. This predictive power appeared to be reinforced by the effects of covariates including previous mathematics learning and the covariate students' motivation towards learning mathematics. Thus, while on the whole, ability had a significant effect on students' achievement in mathematics, the effect was probably also influenced by other variables. Variables with such influence, included probably previous mathematics learning at appropriate levels. Learning of this kind, could take place during play in the home environment and in early formal school. During such learning, basic logico-mathematical structures necessary for good mathematics achievement in latter school could be developed.

Sex Factor

Overall Effect. The present study found no overall statistically significant effect of the sex factor in Students' Achievement in Mathematics (SAM). Zambia's practice of offering mathematics in the school curriculum without discrimination on grounds of sex, thus appeared supported.

Studies reviewed (Ausubel, 1968; Klausmeir and Goodwin, 1966; Meece et al., 1982; and others) appeared to have focussed more on relative performance of male and of female students in different sections of mathematics. However, Vernon (1950), after reviewing factorial studies related to mathematics, concluded that only very few students might have "special flairs" in special study sections of mathematics such as algebra, geometry and others. Vernon thought any suspect flairs might be accounted for by the way these different sections of mathematics are taught. The present study, only focussed on the overall effect of sex on students' achievement in mathematics. The mathematics course content taught included introductory concepts to the Algebra of Sets and Euclidean Geometry of Solid Shapes.

Grade Seven Selection. Annual selection from grade seven completers in Government Grade Eight classes in Zambia is on the basis of candidates' aggregate scores in the Zambia National Grade Seven Composite Selection Examination. Selection cut-off points vary according to : the number of available Grade Eight school places country-wide; the province of Zambia for which the selection is made;

whether the school for which selection is made is a day or a boarding school; the sex of the student being selected. Selection is biased on the sex factor towards accepting a lower aggregate cut-off score point for girls. The bias is thought necessary so as to redress Zambia's inherited pre-independence legacy of less educational opportunity for women (Educational Reform Reports, 1975).

In recent years, due to shortage of school places in Zambia, over eighty percent of candidates for Grade Eight classes have not been selected (Njobe, 1983:25). Consequently, the selection exercise tended to be a sensitive issue. Cut-off points vary from year to year according to their fore-listed determinants. Cut-off points are thus not easy to quote as they vary and data on them proved not easy to come by.

One disadvantage of varied cut-off selection points might be to bring into the selection process a subjective element. Differing cut-off points enable students with less scores to gain Grade Eight places at the expense of students who had scored higher in the selection examination. However, on the other hand there is much to be said for varying the cut-off points to enable disadvantaged groups in the Zambia population of Grade Seven completers to be redressed.

The schools used for the present study, Kabulonga Secondary School for Boys and Kabulonga Secondary School for Girls, provided comparable numbers of Grade Eight school places for students of each sex. Both schools are Day schools situated in the same capital city of Zambia. Thus the main difference in the selection, into the Grade Eight classes of the two Kabulonga schools which provided the population for the present study, was in the different Grade Seven aggregate cut-off score points used in selecting the male and in selecting the female students.

Consequent upon the use of different cut-off score points as indicated above, further data analysis result (Table 1) on page 65 above, showed that the sample male students had, on the whole, a higher ability (Grade Seven Aggregate mean score) than the sample female students taken as a whole. Therefore, that the study found no significant differential effect of the sex factor on SAM, might well be credit to the female students' performance since, on the whole, their ability (Grade Seven Aggregate mean score) was lower than that of the male students (Table 12). The following discussion on subgroup performances according to sex, might shed more light on the foregoing suggestion of credit to female students.

Subgroup Achievements According to Sex. Additional data analysis (Table 10) of the SAM mean scores of all the high ability male (n = 24) and all the high ability female (n = 24) students of the study sample, irrespective of method of instruction, showed that the SAM mean score (47.79) of the high ability male students was higher than the SAM mean score (41.295) of the high ability female students. On a t-test however, the difference between the two means was not statistically significant ($t = 1.49$, $df = 46$, not significant at $p = 0.05$).

Further data analysis comprising t-test comparisons (Table 10) which took into account differences in the method of instruction used, revealed the following. Under heuristic instruction, the resulting SAM mean score (49.83) of the high ability male students ($n = 12$) was significantly higher than the corresponding SAM mean score (37.67) of the high ability female students ($n = 12$) where $t = 2.28$, $df = 22$, was significant at $p = 0.05$. Under the expository method of instruction however, the resulting SAM mean score (45.75) of high ability male students ($n = 12$) and the corresponding SAM mean score (44.92) of the female high ability students ($n = 12$) appeared to hardly differ from each other.

These findings seem to suggest that, on the whole, the high ability male students achieved better than the high ability female students. The heuristic method of instruction appeared to account more for this observation than the expository method did. Heuristic instruction has been favoured over expository instruction in some studies (Dörner 1978; Philip , 1973; Husén , 1967; and others).

However, the result of additional data analysis summarised in Table 1, suggested a need for caution in accepting the present study' conclusion that high ability males achieved better than high ability females. Table 1 results showed that the ability (Grade Seven Aggregate mean score) of the high ability male subgroup was significantly higher than the ability mean score of the high ability female subgroup ($t = 4.639$, $df = 46$, significant at $p = 0.001$). The result of additional data analysis of SAM mean scores of low ability subgroups (Table 8) also did not appear to support a suggestion that, on the sex factor per se , the male students were better achievers than female students in mathematics.

Additional data analysis based on t-test comparisons of SAM mean scores of all the low ability male ($n = 24$) and all the low ability female ($n = 24$) students of the study sample, irrespective of subgroup methods of instruction used (Table 10), is reported upon below. The SAM mean score (37.33) of the low ability female subgroup ($n = 24$) was higher than the SAM mean score (34.33) of the low ability male subgroup ($n = 24$). However the difference between the two means was not statistically significant. Further study of the observation appeared necessary.

Thus, the male low ability subgroup appeared to score less than the female low ability subgroup in mathematics even though the difference of the two means was not statistically significant. The foregoing finding was observed despite the result of additional data analysis summarised in Table 1. The result in Table 1 showed that male low ability subgroup had a significantly higher ability (Grade Seven Aggregate mean score) than the female low ability subgroup ($t = 50.06$, $df = 46$, significant at $p = 0.001$).

Thus the SAM mean scores of male sample subjects, did not appear "indisputably higher" than those of female subjects as Ausubel (1968:242) suggested. However, subjects referred to in Ausubel's review of studies were from different cultural settings from that of the present study sample. Never-the-less, Ausubel's further suggestion that differential conditions of cultural expectations, motivation and opportunity might account for observed sex related difference in achievement, probably holds also for the present study finding on mathematics achievement and the sex factor.

Sex related discriminatory socialisation practices in the culture, might give rise to sex related differences in SAM. This might be through influence of the practices on attitude toward mathematics, related motivation and acquisition of basic logico-mathematics structures during the child's early life in the home environment. On the latter, differentials in access according to sex, to relevant play experience might be important. Previous mathematics learning, attitude and motivation were controlled in the present study.

On the foregoing and on other accounts, the sex factor might have emerged non-significant. The latter result might then indicate that with socialisation related variables controlled, male and female students might achieve equally. However, if females continue to experience adverse discrimination in expectations, opportunity, cultural socialisation practices and so on, males might continue as a consequence thereof, to appear better achievers than girls in school and perhaps elewhere.

Earlier, the present discussion reported that the ability factor was found to have an overall statistically significant effect on students achievement in mathematics. The effects of sex and method of instruction had not been taken into account in that overall finding on ability. The high ability students were found to achieve better than the low ability students. However, further data analysis taking into account the sex factor appeared to suggest that a sample subgroup with a low ability (Grade Seven Aggregate mean score) might score higher than a sample subgroup with a higher ability mean score when the sex and the ability factors were taken into account simultaneously. Probably the ability factor did not fully account for the differences observed in students' achievement in mathematics. Effects of other factors were probably also at play. The discussion of the result of further data analysis which followed, perhaps helped towards more understanding of the factors affecting students' achievement in mathematics. The analysis took into account the effects of the methods of instruction used for the low ability sample subgroups of either sex.

The results of the further analysis of SAM scores which took into account differences in methods of instruction used for low ability subgroups of either sex were summarised in Table 10. The summarised result was then discussed as follows.

The low ability female subgroup (n =12) had a higher SAM mean score (35.42) than the SAM mean score (33.50) of the low ability male subgroup when both subgroups were taught by the heuristic method of instruction. However, the difference between the two means (Table 10) was not statistically significant. Similarly, the low ability female subgroup (n =12) had again a higher SAM mean score (39.25) than the SAM mean score (35.17) of the low ability male subgroup when both subgroups were taught by the expository method of instruction. Again however, the difference between the two means (Table 10) was not statistically significant. Thus, irrespective of method of instruction, low ability female students appeared to achieve better in mathematics than low ability male students. Under either method of instruction however, the SAM mean score differences were not statistically significant.

The result of the additional data analysis summarised in Table 11 earlier, was again perhaps, also necessary to be borne in mind when interpreting the foregoing observations. Table 1 summary showed that the ability (Grade Seven Aggregate mean score) of the low ability male subgroup was significantly higher than the ability mean score of the low ability female subgroup.

On the basis of the comparisons presented above, the achievement in mathematics according to sex of the present study sample subgroups, at the high and at the low levels of ability, it might be concluded as follows. When the sex factor was taken into account, ability factor effects, earlier found with overall statistical significance, were unable to account fully for the differences observed in students subgroup achievements in mathematics.

Although male subgroups – with significantly higher ability (Grade Seven Aggregate mean scores) – appeared to achieve better in mathematics under the heuristic and under the expository methods of instruction, the situation appeared reversed among low ability male and female subgroups. Among the latter, low ability female subgroups appeared to achieve better than low ability male subgroups. However, the differences in the SAM mean scores were not statistically significant. Worthy of note however was that: the low ability female subgroups scored higher than the corresponding "low ability" male subgroups under either method of instruction used in the study. The observation appeared, notwithstanding another present study finding from additional data analysis that, the low ability male subgroups had significantly higher ability (Grade Seven Aggregate mean score) than the female subgroups.

The effects of ability, sex and some references to method of instruction, so far discussed, were only based on part of the study data analysed. Thus firm generalisations and conclusions on overall were not yet possible until the effects of instruction methods, main factor interactions and covariates were also discussed. Probably the following findings at least could be tentatively stated as already apparent.

Ability as measured by the Zambia National Grade Seven Composite Selection Examination has an overall significant effect on the mathematics achievement of students entering secondary school in Zambia. High ability male students tend to respond better than female high ability students to heuristic method of instruction during these students' early experiences with secondary school mathematics. If socialisation practices according to sex in Zambian society, as elsewhere in Africa, tended to expect women to be more dependent on men than on themselves in finding solutions to daily life problems, then boys might learn to be better responsive than girls to heuristic (discovery) situations. Thus boys' mathematics achievement might remain higher than that of girls under heuristic instruction. The tendency might be more so if boys, as in this case , have an ability (Grade Seven Aggregate mean score) edge over the girls.

Otherwise, female students of high ability, appeared to achieve equally well as male students of high ability when both groups are taught by expository method of instruction. Female students of low ability however, might tend to achieve as much as, if not better, than corresponding low ability male students, if the mean abilities of the two sex groups were well matched.

In conclusion therefore, the present study found no firm evidence of an overall or subgroup difference in mathematics achievement of the male and of the female students of matched (equal) ability. The finding probably holds whether the two sex groups were taught by the heuristic or were taught by the expository method of instruction. Probably therefore, the sex factor has no overall significant effect on the mathematics achievement of Zambian students beginning a secondary school course in mathematics. However, the male students might initially appear to respond better than the female students to mathematics teaching when the heuristic method of instruction is used. Whether such a difference would persist throughout the teaching of the secondary school mathematics course, might need further investigation. The male and the female subgroups when matched in ability, probably do not score significantly different when taught by the expository method. But high ability males might tend to score better than high ability females when taught by heuristic method of instruction.

Method Factor

Introduction. The effects of the methods of instruction on Students' Achievement in Mathematics

(SAM) were discussed as presented below. A brief outline of the setting in which the investigation of methods of instruction took place preface the discussion. The findings on the main effects of the method factor was discussed next and related to the literature reviewed. The findings of additional data analysis comparing the effects of the two methods of instruction on : the high ability male subgoups; the high ability female subgroups; the low ability male subgroups; and the low ability female subgroups was then discussed. All the findings on the effects of the method of instruction were then discussed with reference to findings of studies related to problems of primary school mathematics learning and teaching in Zambia. Tentative generalisations, conclusions and recommendations punctuated the discussions.

The investigation into the effects of methods of instruction commenced immediately the sample students were admitted into Grade Eight in the two study schools. Thus the mathematics study lessons taught, also served to introduce the students to Zambia's Junior Secondary School Mathematics course. In each of the two unisexual study schools, an experimental and a control class had been randomly constituted. The resulting four study classes were all taught the by the researcher in person . The purpose was to control teacher related variables.

The experiemental classes were taught by the study heuristic method while the control classes were taught by the expository method of instruction. The instruction material consisted of introductory concepts to the Algebra of Sets and to the Euclidean Geometry of solid shapes. Each class had fifteen contact hours for instruction and administration of instruments. The hours were spread over five consecutive weeks. That is, each class had on the average five periods of forty minutes each per week.

Main Effects of Instruction Method. The result of data analysis summarised in Table 6 showed that the main effects of the method factor had $F(1, 94) = 1.104$ not significant at the $p=0.05$ level selected for the present study. The finding concurred with Wallis (1961) that there appeared to be no consistent set of hypotheses regarding the relative efficacy of student discovery and teacher dominated methods of instruction. Perhaps one reason, from the experience of the present study, could be the ever possible interference of the main and interaction effects of other variables in a classroom study. One of the variables could be interaction of type of method of instruction and pupil characteristics.

Hugh Philip (1973) in another study, suggested that the discovery method of instruction be prescribed for teaching mathematics in developing countries. Zambia is a developing country. However, the present findings do not appear to support such a recommendation without qualification, as now follows.

Only the sample, twenty five percent, high ability male students appeared to score better (Table 8) under heuristic (discovery) method than under the expository method. However perhaps, whatever little might be learnt through discovery, and therefore probably with more understanding, might have more chance of being applied to solve problems of development by school leavers compared to much of what might be learnt by rote under expository instruction. The present study assumed that the seventy five percent of the sample subjects, scoring less under discovery (heuristic) than under expository, might have been more hampered by a shortfall in previous experience with heuristic mathematics learning. The study had found previous mathematics learning to be a significant factor in later students' achievement in mathematics. Also, low ability might interact with other student characteristics and/or class dynamics. The result might then be higher achievement under expository than under heuristic for some in the seventy five percent.

Previous experience with heuristic learning could be gained informally during childhood in the home environment and formally in early school. Perhaps therefore, an early orientation of children - during the early home socialisation and early formal school - towards habits of discovery such as solving problems by discovery, appears to be a necessary pre-requisite to a general prescription of the use of the discovery method as suggested by Hugh. Perhaps only thereafter could there be reasonable hope for more productive mathematics learning from heuristic instruction compared to expository instruction.

On the balance therefore, considering the present study findings on the main effects of the method factor and the result of additional data analysis of subgroup achievements according to ability and sex, students starting the junior secondary school mathematics course in Zambia appeared to respond better to the expository than to the heuristic method of instruction (Table 8). Perhaps the effects on Zambian pupils of pre-school experience at home and in primary school mathematics learning were material. Where the pre-school socialisation experience and primary school teaching accustom pupils to discovery learning, Hugh Philip's recommendation of a use of discovery method at the secondary school might produce the desired result. In selecting either a heuristic or an expository method of instruction, teachers in Zambia, might need to take into account the previous instruction method experience of their pupils. Any introduction of a method of instruction less familiar to the pupils might then need to be made gradual.

Discussed below are the finding of additional data analysis of the effects of the method factor on SAM mean scores of sample subgroups. The purpose was to search for further insights on the effects of the study methods of instruction on Students' Achievement in Mathematics (SAM).

Instruction Methods and Subgroup Achievements. The result of additional data analysis, based on t-test comparisons of the effects of the methods of instruction was summarised in Table 11 on page 130. The result was then discussed as follows.

The SAM mean score (41.67) of the subgroup of male students (n = 24) taught by heuristic method was slightly higher than the SAM mean score (40.46) of the subgroup of male students taught by the expository method of instruction (n = 24). However the difference between the means was not statistically significant (Table 11). Thus on the whole, method of instruction did not appear to show a significant differential effect on the mathematics achievement of male students in this study.

Similarly, the SAM mean score (49.83) of the subgroup of male students of <u>high ability</u> (n = 12) taught by heuristic method was not significantly higher (statistically) than the SAM mean score (45.75) of the corresponding high ability male subgroup (n = 12) taught by the expository method of instruction. On the other hand, the low ability male subgroup (n = 12) taught by heuristic method had a slightly <u>lower</u> SAM mean score (33.5) than the SAM mean score (35.17) of the corresponding low ability male subgroup (n = 12) taught by expository method of instruction.

Again the difference between the two means was not statistically significant. .

Thus the high ability male subgroup scored slightly better under heuristic than under expository instruction. The low ability male subgroup on the other hand, scored slightly better under expository than under heuristic instruction. The scores of the male high ability subgroup (n = 12) taught by heuristic method, appeared to account for the apparent overall observation that the subgroup of male students (n = 24) taught by heuristic method scored slightly better than the subgroup of students (n = 24) taught by expository method of instruction.

Table 11, also showed that the SAM mean score (36.54) of the female students subgroup (n = 24) taught by heuristic method was lower than the SAM mean score (42.08) of the corresponding subgroup of female students (n = 24) taught by the expository method. The difference between the means however, was not statistically significant (Table 11). Similarly, the SAM mean score (37.67) of the high ability female subgroup (n = 12) taught by heuristic method was lower than the SAM mean score (44.92) of the corresponding high ability female subgroup (n = 12) taught by expository method. Again the difference between the means was not statistically significant (Table 11). The low ability female subgroup (n=12) taught by heuristic method also had a lower SAM mean score (35.42) than the SAM mean score (39.25) of the corresponding low ability female subgroup (n=12) taught by expository method. The difference of the means was again not statistically significant. Thus equivalent high ability female subgroups as well as equivalent low ability female subgroups appeared to respond less favourably in SAM when taught by heuristic than when taught by expository method. However, the differences between corresponding SAM mean scores were not statistically significant.

Further close comparative examination of the posttest and pretest scores of the subgroup of low ability female students (n=12) taught by heuristic method, the following observation was made. Five out of the twelve students had a lower mathematics mean score (30.2) in the posttest than their mathematics mean score (40.2) in the pretest. However the difference was not significant (t=1.229, df=4, not significant at p=0.05). The foregoing lower posttest than pretest scores, were found only among the low ability female students taught by heuristic method. Perhaps low ability female students in this case, experienced something retarding under heuristic instruction. Lesson presentation requires more time under heuristic than under expository instruction. The equal time allocated in the present study might have adversely affected subgroups taught by heuristic method in speed of subject material coverage. Low ability students might have suffered most. SAM scores were probably correspondingly affected.

Thus both methods showed no statistically significant difference on SAM : either on considering the overall of the entire sample (Table 6); or among the male or among the female sample subgroups; or among the high ability or among the low ability subgroups in either sex category (Table 11). On face value, this foregoing finding appeared to suggest that the two methods of instruction used in the study had no significant difference on subgroups of subjects. In that event, the two methods of instruction would be expected to have no differential main or interaction effects on SAM mean scores of equivalent subgroups.

However, the foregoing observed effects of the methods of instruction were probably not so simple since the present study also found a statistically significant method-sex interaction. That is, the effects of the heuristic and the effects of the expository methods of instruction appeared to influence students' achievement in mathematics in such a way that the male students were influenced slightly differently from the female students. The following discussion of additional data analysis appeared to suggest that the effects of the methods differed.

Though the SAM mean score differences referred to earlier did not appear statistically significant, the magnitude of the differences varied. The differences (Table 8) appeared slightly larger among female subgroups' SAM mean scores than among male subgroups' SAM mean scores. In all three cases of comparison of pairs of female subgroups (Table 11) discussed, the SAM mean scores resulting from heuristic instruction (table 11) were lower than the corresponding SAM mean scores resulting from expository instruction. However, among the cases of comparison of pairs of male subgroups (Table 11) discussed, in two of the three cases the heuristi instruction appeared to yield higher subgroup SAM mean score than the expository method of instruction.

Thus students appeared to respond better in mathematics achievement to heuristic than to expository instruction among the high ability males. However, among the low ability male students the reverse appeared to be the case. That is, the students appeared to respond better in mathematics achievement to expository than to heuristic instruction. Female students of high and of low ability appeared to respond better to the expository than to the heuristic method Thus all female subgroups (n = 48) and the low ability male subgroup (n = 24) achieved better under expository than under heuristic instruction. However, some students in the group might prefer a combination of both heuristic and expository.

Thus approximately seventy five percent (n = 72) of the study sample subjects (N = 96) probably did better under expository than under heuristic instruction. The reasons might include the following: The subjects might have been more accustomed to expository kinds of instruction in their former primary schools; The idea of the students being required to "discover" answers on their own might have been unusual to the students both in their experience at home and in learning at the primary school level and perhaps also in the community cultural socialisation experience. The students mostly might have been used to 'doing as told' in the home and community with adults normally providing answers to problems the children encountered. On attending school, the tendency might still be to expect or prefer the teacher, as parent substitute, to continue providing answers during lessons. Yet, students' success in discovery learning might also depend on creative thought and self confidence in being able to discover. Perhaps not many students easily command such confidence in mathematics where heuristic problem solving was not common in earlier experience.

Since the expository method appeared, on the whole, more effective than the heuristic method, it might be suggested therefore that the two study methods of instruction did have some differential effects no matter how limited. The effects of the other variables and variable interactions including the method-sex interaction effect, might have confounded differences between subgroup SAM mean scores compared on the basis involving the effects of the sex and the method factors. The confounding might partly explain the high incidence of non-significant t-ratio comparisons of sex and method subgroup SAM mean scores.

Literature reviewed did not show any direct Zambian studies on the effects of method, sex and ability on secondary school students' achievement in mathematics. However, Zambian studies on the: National Grade Seven Composite Selection Examination (Ming, 1975; Sharma, 1974); primary school English medium of instruction (Chishimba, 1979; Chishimba, 1980; Shana, 1980; Chikalanga, 1983; Lawrence and Servan, 1983; and others); quality of primary school teacher training in Zambia (Gagne, 1975; Chishimba, 1980; Waddimba, 1982); appeared relevant to the present study search for insights into the problem of mathematics achievement among Zambian secondary school students. The forementioned studies were thus dicussed as presented below.

The studies by Ming (1975) and Sharma (1974) were more related to Zambia's National Grade Seven Composite Selection examination. Ming (1975) found the non-verbal reasoning test, of the six tests of the composite examination, to be a more "useful and valid predictor" of students' later performance in secondary school technical courses. However, one other question apparently unanswered by the study was, what was wrong with the verbal tests ? Did the students perhaps, experience a language problem with the verbal tests ? If so, could such a problem result in reduced predictive value of the tests ?

Sharma (1974) on the other hand, found a weak correlation ($r = 0.460$) between the scores of sample of candidates from the 1972 National Grade Seven Composite Selection examination and the sample's later scores in Grade Nine tested by a specially devised criterion examination in mathematics. Sharma also did not appear to have directly addressed the problem of English language used as a medium of instruction in the primary school.

Perhaps, the discord in Sharma's expected high correlation, like the problem of a weak or lacking predictive power in verbal tests found in Ming's study, were partly due to the problem experienced by the students in learning through the English medium of instruction in the primary school. Vernon (1950:39-40) found that on factor analysis, mathematics attainment showed a linguistic component. Primary school children in Zambia have been said to find difficulty with the prescribed English medium of instruction (Chishimba, 1980; Chikalanga, 1983). Lawrence and Sarvan (1983) concluded that Zambian primary school pupils, faced with the problem of attaining fluency in standard English, probably evolved and functioned on an "inter-language". The inter-language was described as being probably inbetween the standard English and the pupils' home languages. Students more fluent in some inter-lamguage or non-standard form of English, might experience conceptualisation problems when taught in standard English. Class participation requiring the learners also to 'discover' answers during lessons might also consequently prove difficult.

The learner speaking non-standard English might find difficulty in appreciating the full meanings of some concepts in mathematics presented by text-books, teachers and examined in tests through the medium of standard English. On beginning the secondary school mathematics course, the communication problem might persist during mathematics instruction given by the college and university trained secondary school teachers. The latter teachers, most probably would speak standard English fluently during lesson presentations.

The effects of teaching mathematics through a language medium in which the learner is not fluent, might even be more retarding to the student because of the presence in mathematics, of a relatively large component of abstract concepts. The learner might feel confronted with strange concepts presented in a semi-intelligible language. The subject material presented might then tend to appear isolated from meanings it should convey. Sizeable sections of the material learnt this way might remain as unsub-sumed entities in the cognitive structure (Ausubel 1968). Mathematics learning of the kind could therefore be described as rote learning. Probably pupils resort to rote learning as a way out of a predicament such as when the ego might feel threatened by an inability to follow what is being said in a lesson presentation. There could then be a real fear of being seen as stupid on account of failure to comprehend the teacher's lesson presentation or questions asked.

The expository method of instruction, in which the learners are passive receipients of knowledge, might then be less embarrassing and probably ellicit better learning (probably rote) response than the heuristic method of instruction, The present study found the female students of high and of low ability as well as male students of low ability - seventy five percent of all the sample students - apparently responding better in mathematics achievement to the expository than to the heuristic method of instruction. Expository instruction is perhaps more open to rote learning than heuristic instruction.

Gagne (1975) found the quality of Zambia's primary school teacher training very unsatisfactory. Mathematics teaching could thus also have been affected. Waddimba (1982) found that the output of Zambia's primary school teacher training colleges prior to 1972, fell far short of what was required.

If the above observations on problems of English language medium of instruction, unsatisfactory quality of primary school teacher training and the prior 1972 insufficient teacher colleges' output, were valid, one suggestion might be the following. Many of the inadequately trained teachers might have also had a poor mastery of mathematics themselves. At Zambia's independence in 1964, mathematics was not among the most popular school subjects[1] Most of the Zambian primary school teachers with training problems about that time might probably have not been quite at ease with mathematics. Consequently the effectiveness of mathematics teaching might have been limited accordingly.

Teachers with a limited understanding of the subject matter might tend to retard the student's own effective learning of what is taught. In mathematics, such a poor teacher might feel not quite confident to answer all questions from the pupils on the subject matter taught. The teacher might then tend to restrict students' questions from straying into areas of mathematics the teacher fears. A student's fuller understanding of mathematics concepts taught becomes limited accordingly.

Defective teaching of the foregoing kind might be expected to be more inclined to be expository than heuristic. Thus most students of the present study sample were probably mostly taught their primary school mathematics course by expository than by heuristic instruction. Probably then, the present study period of instruction of five weeks was not long enough for allowing the reactions of the study sample subgroups to stabilise adequately to the respective methods of instruction. The reactions of the sample students to either of the study methods of instruction probably varied according to the method of instruction each student was accustomed to in the primary school. Some students might have preferred the old familiar primary school method of instruction which ever, while others might have preferred the novel method of instruction which ever. Where the students' foundation in mathematics was weak however, the expository instruction might have been more appealing.

If students in Zambia were generally poor in mathematics as suggested[2] then the students might initially be expected to respond more favourably to the expository method than to the heuristic method. The tendency might be enhanced if the heuristic method was not commonly used in the primary school.

The present study revealed that all the female sample student subgroups and the low ability male sample students - constituting together seventy five percent of the total sample students — had higher SAM mean scores (Table 8) when taught by expository than when taught by heuristic method. The sample subgroup SAM mean score differences (Table 11) were however not statistically significant. Perhaps, if the kind of student subgroup stabilisation to instruction methods suggested earlier had been achieved, as through longer study instruction periods, the fore-mentioned mean differences might have become wider. A repeat study with a longer period of instruction might therefore be useful.

Perhaps the following observation, already reported earlier in this discussion in more detail, might be related to the suggested student initial reaction to change of method of instruction. In that report, five out of twelve students constituting the low ability female subgroup taught by heuristic method, were found to score lower at the posttest than at the pretest. However the difference between the pretest and the posttest mean scores of the five students was not significant ($t = 1.229$, $df = 4$, not significant at $p = 0.05$). Never-the-less, the students' reaction to heuristic instruction could have been at play. Further investigation on the phenomenon might be necessary.

The present study experience with instructing through heuristic method, often revealed student difficulty in freely tendering "discovered" answers in class. Considering the Gestalt hypothesis, the implicit suggestion is that a learner to be able to discover, might need the capacity to transform a pattern of concepts and means-ends relationships into a discovered solution to the given problem. Thus there should be a reasonable infrastructure of knowledge, skills and language proficiency in the learners cognitive structure to enable the discovery to take place. A student deficient in language fluency and with gaps in already acquired basic logico-mathematical structures and concepts, might well tend to reduce the student's capacity to cope with heuristic instruction. Consequently a teacher's intended heuristic instructional approach might come under pressure towards degenerating into an expository instruction. This might happen as the teacher becomes pressurised to intervene more often than desirable for a heuristic instruction. Interventions of the kind might take the form of giving too many clues in an effort to rescue the lesson from grinding to a halt. The present researcher had often occassions, consciously to resist pressures of the foregoing kind during some of the heuristic instruction lessons.

If teaching in Zambia's primary schools failed to lay a strong mathematics foundation, students advancing to secondary and higher levels of education might experience difficulty with heuristic instruction. Primary school failure to teach effectively, might result from problems such as pupil difficulty with English language medium of instruction and inadequate teacher training. Students' inability to cope with discovery (heuristic) kind of learning, might limit the students' indepth mastery of some concepts and skills in mathematics. School leavers might then still feel less confident to apply the mathematics knowledge acquired to life situations requiring related discoveries.

Firm generalisations and conclusions on the effects of method of instruction on students'achievement in mathematics need to await the following discussion on the effects of factor interactions and covariates. The first discussion below is on the method-sex interaction found in the present study to be statistically significant.

Main Factor Interactions

The interactions of the main factors of this study were discussed as follows. The method-sex interaction effect on students' achievement in mathematics was discussed first. Summary results of additional data analysis of observations on method effects among sample subgroups were discussed next. Tentative generalisations, recommendations and conclusions on the method-sex interaction findings were then made. Other main factor interactions, found statistically non-significant were noted at the end.

Method-sex Interaction. The summary data of Table 1, showed a method-sex interaction effect on Students' Achievement in Mathematics (SAM) significant at $p=0.035$, $F(1, 94) = 4.477$ .Thus the effects of methods of instruction on the mathematics achievement of the male and of the female students were not uniform. The method of instruction appeared to influence students' achievement in mathematics in such a way that the male students were influenced differently from the female students.

Earlier, in the discussion on the effects of the method factor on SAM, the findings noted (Table 11) included the following. The SAM mean score (41.67) of the subgroup of male students ($n = 24$) taught by heuristic method was slightly <u>higher</u> than the SAM mean score (40.46) of the subgroup of male students ($n = 24$) taught by expository method. The difference between the means was however, not statistically significant (Table 11). Thus on the whole, inspite of the non-significant difference, there seemed to be a suggestion that the mathematics achievement of male students was better under heuristic than under expository instruction.

On the other hand (Table 11), the SAM mean score (36.54) of the subgroup of female students (n = 24) taught by heuristic method was <u>lower</u> than the SAM mean score (42.08) of the subgroup of female students (n = 24) taught by expository method. Thus on the whole, the mathematics achievement of the female students appeared better, though statistically the difference was non-significant, under expository than under heuristic instruction.

Thus on the whole, heuristic instruction appeared to yield a slightly <u>higher</u> SAM mean score among the male students than expository instruction. On the other hand, on the whole, heuristic instruction appeared to yield a slightly <u>lower</u> SAM mean score among the female students than the expository instruction. Thus the effects of method of instruction on the mathematics achievement of the male and of the female students appeared slightly different. Heuristic instruction might have made male students achieve <u>better</u> than expository instruction while heuristic instruction, on the other hand, might have made female students achieve <u>less</u> than expository instruction. To investigate the same observation further, additional analysis of data of sample <u>ability</u> subgroups was made.

From the result of the further analysis (Table 11), the following also became apparent. The high ability male subgroup achieved slightly better under heuristic than under expository instruction. On the other hand, the high ability female subgroup achieved slightly less under heuristic than under expository instruction. However, the differences between the means in either case were not statistically significant.

Among low ability male and low ability female subgroups however, the method of instruction did not appear to show a differential influence on SAM. Both low ability male and low ability female subgroups appeared to achieve slightly better under expository than under heuristic instruction (Table 8). Probably therefore, the entire capacity to discover became equally limited for both the male and the female students of low ability.

Ausubel (1968:241-243) in a brief review of literature related to sex differences and intellectual performance, concluded that differences in variability of performance of males and of females "when found are mostly marked at the extreme of the distribution". Thus the present study variation in mathematics achievement - probably due to a method versus sex interaction effect - found apparently only among the high ability student subgroups, was perhaps not inconsistent with Ausubel's foregoing observation.

Differences in mathematics achievement that might be accounted for in terms of physiological differences associated with sex are difficult to imagine. However the influence of differing social prescriptions of expectations, availed opportunity, sex roles and practices of socialisation into the culture according to sex, might explain some sex related differential effects of methods of school instruction on SAM.

Ausubel (1968:242) in the above mentioned review of literature on sex differences and performance, suggested that "differential conditions of cultural expectation... and opportunity cannot be ignored". Witkin (1967) suggested that socialisation practices in the culture in which a child grows, might determine the kind of cognitive style the child acquires. The two main styles suggested, in this view, were the ones in which the individual might become either:more articulate in perception and thinking (Field-independent) - probably more appropriate for effective response to heuristic than to expository instruction; or more global in perception (Field-dependent) and thus often finding difficulty to impose structure or differentiate items. A field-dependent style might then be more common with learners that tend to be happier with expository than with heuristic instruction.

Witkin suggested that field-independent cognitive style might result more from a cultural socialisation in which parents encourage the child towards separation, autonomous functioning and so on. Perhaps the way the parent also allowed free expression of impulse and opinion might be important in the development of the field-independent kind of cognitive style. Field-independent students might correspondingly find opportunity for fuller expression in a heuristic than in the more passive learner oriented expository instruction.

Female students might be expected to respond more favourably than male students to the more passive expository instruction where the following social practices exist. (i) More permissiveness is shown to boys than to girls in allowing more free choice of, and expression of impulse, opinion and action. (ii) Boys are expected more than girls to be involved, away from the more rigid parental control, in outdoor activities. Such activities might include those often observed in Lusaka as apparently providing opportunity for initiative and discoveries. The Lusaka independent play activities of boys often include the making of wire toy cars, bicycles and kites. The girls, on the other hand, appear to be often expected to be confined to the home under parental control. Thus girls might tend to appear subdued and consequently respond best to the expository than heuristic instruction. This could be expected since heuristic demands independent expression and creative discovery of answers. Munro (1968), in a study of Zambian children in a suburb of Lusaka, found that the male children appeared more free than female children to engage in a variety of local outdoor games and other activities.

Thus differential practices, opportunity and expectations according to sex role prescriptions, during the cultural socialisation process might inadvertently be enabling male students to develop the more field-independent kind of cognitive style than female students – if Witkin (1967) postulate were valid. Consequently the males might appear to respond more successfully than females to heuristic instruction. Mathematics learning, demanding mastery of a sizeable component of abstract concepts, might be learnt more effectively through heuristic than expository instruction. Cognitive learning style acquired by the child during growth, might then be important.

Probably therefore, a method-sex interaction effect of the kind found in the present study, might be expected if the suggested differences in socialisation practices and their suggested possible effects were valid. Similarly, cultures which maintained wide differences according to sex in socialisation practices, opportunity, role expectations and so on, should expect to observe differences in the mathematics achievement of the male and of the female students. Women in many cultures, tend to suffer, though to varying degrees, discrimination of one kind or the other in the fore mentioned aspects of social life. Thus it might be no wonder that Ausubel (1968:241-243), from literature review found that male students "indisputably" appeared to show a higher "incidence of intellectual eminence" compared to female students.

Without prejudice to the foregoing discussion on the method-sex interaction, a caution on some possible consequences of significant main factor interaction needs to be sounded. A statistically significant interaction effect might tend to limit generalisations and conclusions that might be drawn from the observed singular effects of the interacting factors (Nie et al., 1975 : 402). Perhaps, in the present study much of the inconclusive (statistically non-significant) differences of the subgroup SAM mean scores corresponding to the main effects of the method and of the sex factors, might well have been partly due to the statistically significant method-sex interaction effects.

The result of data analysis summarised in Table 6 showed that the interaction effects between method and ability, ability and sex were not statistically significant. Similarly, the three-way interaction among method, ability and sex was not statistically significant. Thus ability - of the three main study factors - did not appear to interact with any of the other two factors.

Covariate Effects

The present study design incorporated for control covariates previous mathematics learning, socio-economic status of the student's home, attitude towards mathematics and motivation towards learning mathematics. The study findings on the covariates were discussed as follows. The effects of previous mathematics learning were discussed first. A discussion on the effects of motivation then followed. Next references were made to the statistically non-significant covariates home socio-economic status and attitude towards learning mathematics. Tentative generalisations, conclusions and recommendations rounded up the discussions.

Previous Mathematics Learning. The study (Table 6) found a highly significant effect of previous mathematics learning on SAM, $F(1, 94) = 4.298$, significant at $p = 0.001$. Thus, what the students learnt earlier in mathematics at the primary school and probably also at the pre-school levels appeared a significant factor influencing the mathematics achievement of the students on entering secondary school. Included in such previous learning might be the effects of influence of curriculum goals, objectives, content, syllabus coverage, availability of resources and other factors. Methods of instruction used by the teachers might also be important.

Previous mathematics learning might also include acquisition of some basics of logic and mathematics (logico-mathematical) structures, as postulated by Piaget in

(Copeland, 1974). The acquisition of basic logico-mathematical structures becomes necessary for more successful conceptualisation in future school mathematics learning. Development of cognitive structures of the kind, might take place during play and action at home, community, pre-school and during formal mathematics learning in the primary school and further.

Perhaps therefore, improving mathematics achievement among Zambian school children needs among other things, increased provision of appropriate play environment for children in the home, community and pre-school. The kind of toys and guided play activities provided in the enviro-ment will need to be appropriate for developing the kinds of logico-mathematical structures future school mathematics will need. Effective formal primary school mathematics teaching could then build on this home, community and pre-school mathematics experience of the child. Thereby, a strong formal foundation for improved mathematics achievement at the secondary school level and further could be laid.

However, Goldberg (1970) in a study of infant care and stimulation in homes in the Matero suburb of Lusaka, found "little intentional developmental stimulation or concern for intellectual ... development" of children in *the homes and surrounding community. There might be need therefore to give special attention and study of child* rearing practices, relevant to future mathematics learning, among Zambians. Insights derived from such studies, might indicate ways by which mathematics achievement among Zambian school children might be improved. Improved mathematics achievement of Zambian students might also contribute toward improving the students' achievement in science and technical subjects. National development could thereby ultimately benefit.

Motivation. The present study (Table 6) found covariate motivation effect significant on students' achievement in mathematics, $F(1, 94) = 4.298$, significant at $p=0.039$. Lindgren (1972:21) described motive as a "pulling force" towards the act of learning in the present context. Maslow (1970) suggested that man should always be seen as desiring something. That is, there is always room for motives in man. McClelland (1961) suggested that students motives to learn mostly originate from needs for achievement, power and affiliation.

Probably therefore, efforts to raise mathematics achievement of students in Zambia should include studies to discover the kinds of mathematics related needs which might "pull" the students towards more effective learning of mathematics. Effective mathematics learning situations could then be organised in such a way as to bring together into play as many of the basic needs and drives, such as suggested by McClelland and others.

Other Study Covariates. The present study found the effects of the other two study covariates, students' home socio-economic status and students' attitude towards mathematics, non-significant at p=0.05 (Table 1). The F ratios were respectively, $F(1, 94) = 0.076$ and $F(1, 94) = 1.893$. Thus the student's home socio-economic status and the student's attitude towards mathematics did not appear to have a differential influence on students' achievement in mathematics.

Wiley (1971) in one study concluded that social stratification in sub-Sahara was less structured in colonial times because of kinship ties, scarcity of technological resources to produce surplus, land tenure policies and other factors. The event of colonisation also brought into the colonies the coloniser's foreign form of education. The foreign education sowed the seeds of a new form of social stratification.

In pre-colonial socities, traditional rulers often formed the highest strata of society. A new political elite emerged during the struggles for independence to form a leadership strata of society often displacing the traditional rulers from the apex of social stratification. Then institutions of higher education modelled on the coloniser's system of education also came into being with important influence on post independence stratification of the new societies. In Zambia, Kaniki (1982) found that the University of Zambia was able to initiate students from fairly humble homes into living styles of an employing social class. Thus a new kind of elite vying for a higher position in the strata of society was being produced from the University of Zambia and other higher educational institutions of learning.

Kaniki (1982) had also observed that secondary school boarding institutions were centres in which a new African social class was nurtured. Students, became groomed for life chances and styles foreign to the students' uneducated compatriots. Thus graduates from the institutions, went into the world of work with special aspirations and expectations of jobs and income levels and styles of life thought to be appropriate rewards for the level of education received. The rewards were scaled in value, status and prestige on the basis of the level of education attained. At Zambia's independence, as more and more occupations were available at higher levels of responsibility and status, higher and higher qualifications and incomes became attached to these occupations. Thus, there came in a spiralled ranking about the axis of educational qualification.

Zambian society therefore, was now being structured into a western kind of social strata largely determined by one's wealth. The most educated tending to rise more quickly to the apex of the pyramid. However, Hoppers (1980) found that the educational qualification by itself gradually became necessary but not always sufficient. An occupation with an income status and prestige had to be acquired after being to school in a growing scarcity of expected jobs. In the field of work, Kaniki (1982) found that educated

Zambians also tended to gain preferential access to, and control of public wealth even without ownership. Perhaps management officers of parastatal and other companies might provide an example of the latter.

However, it might be suggested that post independence forms of social strata among Zambians are still in a state of formation. Socio-economic status, from the foregoing brief review, might still attach more to the individuals holding the positions in society rather than to entire family members including children, as in some western societies. Factors pointed out by Wiley (1971), might tend to hold back the process of quick formation of clearly demarcated social strata as known in highly industrialised western societies. Extended family practices, one still observes in Zambian communal life, probably evidence the kind of problems Zambian society might experience towards attaining orthodox forms of western social stratification.

Consequently the home socio-economic status of the study students, of the recently independent Zambia, did not show a significant influence on students' achievement in mathematics.

Students' attitudes towards mathematics might be influenced by a number of factors. These might include the students' previous learning experience with mathematics and the importance the school places on mathematics in the curriculum. On the basis of the attitude hypothesis by Rosenberg (1967), one implicit suggestion for the present study might be the following. The students' attitudes towards mathematics might be determined by the extent to which the students saw mathematics as likely to help or thwart their chances of gaining school leaving certificates and entering careers of their choice. However, in the Zambian primary and secondary school curricula, mathematics is a compulsory subject. Probably therefore, the students might have a limited choice of an attitude towards mathematics. The compulsion might itself be a strong factor in determining the attitude. Consequentl a significant differential effect of attitude on the students' achievement in mathematics might then, be difficu to observe. That the subject is compulsory could have influenced the students' responses to items on the attitude scale. Further studies of students' attitude towards mathematics appear necessary.

Notes

1. Republic of Zambia: Ministry of Education, Annual Report 1964 (Government Printer: Lusaka, page 31)

2. Sunday Times of Zambia. 22. 7. 84. Report of an interview with the Minister of Higher Education.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This final chapter contains the summary of the major findings of the study, conclusions, recommendations and suggestions for further research arising from the findings of the study. The contents of the three subheadings of the chapter were compiled and presented as below.

SUMMARY

Problem The study attempted to answer the following questions. Are there any differential effects on the mathematics achievement of Grade Eight Zambian students accountable in terms of the students' sex, ability and method used to instruct the students ? Are there method, ability and sex two-way and/or three-way interaction effects on SAM ? That is, what are the main and interaction effects of method of instruction, ability and sex on SAM among high and among low ability students of either sex when taught by heuristic and when taught by expository method of instruction ? A corollary question to the foregoing on covariates was, what effects do the covariates students' previous mathematics learning, motivation towards learning mathematics, home socio-economic status and attitude towards mathematics have on SAM ?

Thus the purpose of the study was to seek answers to the foregoing questions. The problem and questions stated above were tackled under a theorectical framework which include assumptions that: students' achievement in mathematics was influenced by the main and the interaction effects of the factors ability, method of instruction and sex; priority covariates to these factors for control were students' previous mathematics learning, motivation towards learning mathematics, home socio-economic status and attitude towards mathematics. Seven null hypotheses and their respective alternatives were formulated and tested on the main and on the interaction effects of ability, method and sex.

Method. The study population was the 1986 Grade Eight student intake into Kabulonga Secondary School for Boys and Kabulonga Secondary School for Girls, Lusaka, Zambia. The Grade Eight intake into each of the schools was about five hundred students. The study sample (N=96) was drawn by stratified sampling. The sample subjects were then randomly assigned to constitute one experimental and one control class in each of the two unisexual study schools.

Five instruments were specially constructed to collect measures of the criterion variable Students' Achievement in Mathematics (SAM) and of the covariates students' previous mathematics learning, motivation towards learning mathematics, attitude towards mathematics and home socio-economic status.

A 2 x 2 x 2 Orthogonal Factorial Experiment design was used for the study. A computer programmed to the Statistical Package for the Social Sciences (SPSS) subprogram three-way Analysis of Variance (ANOVA) with Covariance (Nie et al., 1975), analysed the main study data. The computer output included a Multiple Classification Analysis table showing the pattern of effects of the main factors and the covariates.

Findings

Significant. The findings presented below were significant on two tailed tests at p=0.05 level.

(i) Null hypothesis (h_o) Two. That there is a relationship between Students' Achievement in Mathematics (SAM) and students' levels of ability was supported by F(1, 94) = 17.840 significant at p=0.001 level.

(ii) Null hypothesis (h_o) Four. That there is a sex versus method of instruction interaction effect on SAM, was supported by an F(1, 94) = 4.477 significant at p=0.035 level

(iii) Covariate Previous Mathematics Learning. That previous mathematics learning has an effect on SAM, was supported by F(1, 94) = 29.450 significant at p=0.001 level.

(iv) Covariate motivation towards learning Mathematics. That covariate motivation towards learning mathematics has an effect on SAM, was supported by F(1, 94) = 4.298 significant at p=0.039 level.

Non-significant. The findings presented below were not signifcant on two tailed tests at the p 0.05 level

(i) Null hypothesis (h_o) One, that there is a difference in SAM when students are taught by either a heuristic or by an expository method of instruction.

(ii) Null hypothesis (h_o) Three, that there is a relationship between SAM and the sex of the student.

(iii) Null hypothesis (h_o) Five, that there is an ability versus method of instruction effect on SAM.

(iv) Null hypothesis (h_o) Six, that there is an ability versus sex interaction effect on SAM.

(v) Null hypothesis (h_o) Seven, that there is an ability versus sex versus method of instruction interaction effect on SAM.

(vi) Covariate attitude toward mathematics. That students' attitude toward mathematics has an effect on SAM.

(vii) Covariate student's home socio-economic status. That student's home socio-economic status has an effect on SAM.

Thus students' achievement in mathematics was found, on the whole, to be significantly influenced by: ability as measured by aggregate scores in the Zambia National Grade Seven Composite Selection Examination; method versus sex interaction; covariate previous mathematics learning; and covariate motivation towards learning mathematics.

On the other hand, the study found that students' achievement in mathematics (SAM) was not significantly influenced by the: main factor effects of method of instruction and of sex; main factor interaction effects between method and ability, ability and sex; interaction effects among method, sex and ability; and covariate effec of home socio-economic status and attitude towards mathematics.

Additional data analysis showed that high ability student on the whole, achieved better than low ability students as might have been expected. On the additional analysis, the significant method versus sex interaction appeared to be such that, high ability male students achieved slightly better under heuristic than under expository instruction, while high ability female students achieved better under expository than under heuristic instruction. Otherwise, th male and the female students of lower ability achieved better under expository than under heuristic instruction. However, differences in the foregoing observations were not significant at the p=0.05 level.

CONCLUSIONS

Implications to theory and to practice, of the study findings with respect to rejected and to accepted hypotheses are presented below.

Rejected Study Null Hypotheses. Null hypothesis Two. Th finding which rejected Null hypothesis Two that there is no relationship between Students' Achievement in Mathematics (SAM) and students' levels of ability implies that the alternative substantive hypothesis (h_1) Two stands. That is the study concluded that there is a relationship between SAM and students' levels of ability. Other implications of rejection of Null hypothesis Two include the following. Ability as measured by the students' aggregate scores in the Zambia National Grade Seven Composite Selection Examination, is a predictor of students' achievement in mathematics in the Zambia Junior Secondary School mathematics course. Students' Achievement in Mathematics (SAM), regresses more on ability (Eta = 0.34) than on either sex or on method of instruction. Thus ability more than either method or sex, appeared to be a better predictor of SAM. However, the strength of the regression of SAM on ability was also found to depend on the covariate effects of previous mathematics learning and of students' motivation towards learning mathematics.

Null hypothesis (h_o) Four. Implications of the finding which rejected Null hypothesis (h_o) Four that there is no sex versus method of instruction effect on SAM indicate that alternative substantive hypothesis (h_1) Four stands. That is, the study concluded that there is a sex versus method of instruction interaction effect on SAM. Other implications include the following.

From additional data analysis, the method of instruction influenced SAM in such a way that the male students achieved better under heuristic than under expository instruction in the high ability group. On the other hand, female students of high ability achieved better under expository than under heuristic instruction.

Perhaps the influence - not presently studied - of sex discriminatory socialisation practices, social expectations and availability of opportunity in a culture contributed towards the method versus sex interaction effect found in the present study. A further study of the phenomenon appeared necessary. Otherwise, the study found no evidence to suggest that the sex factor per se had a significant differential influence on students' achievement in mathematics.

Among the low ability male and the low ability female students, the heuristic and the expository methods of instruction did not show the interaction effect between sex and method of instruction. Both the low ability male and the low ability female students appeared to achieve better under expository than under heuristic instruction. Probably the capacity to cope with the discovery demands of the heuristic learning becomes equally reduced and limited in students of either sex in the lower ability range. Perhaps these students then favoured the passive and receptive learning provided by expository instruction.

Accepted Null Hypotheses. Null hypothesis (h_o) One. The implication of the finding accepting Null hypothesis (h_o) One is that there is no difference in SAM when students are taught by either a heuristic or an expository method of instruction. However, in the presence of a method of *instruction versus sex interaction effect, the main effects* of method of instruction, on the overall, might have been obscurred. Hence, the significant method of instruction versus sex interaction probably affected the main effects of method of instruction on SAM. The study therefore concluded that further investigation of the differential effects of heuristic and expository instruction on SAM was necessary.

Null hypothesis (h_o) Three. The finding on Null hypothesis (h_o) Three is that there is no relationship between SAM and sex of the student. The study concluded that all other factors being equal, male and female students achieve equally well in mathematics.

Null hypothesis (h_o) Five. The accepted finding on Null hypothesis (h_o) Five is that there is no ability versus method of instruction interaction effect on SAM. The implication is that the effects of method of instruction are similar on the two categories of ability studied.

Null hypothesis (h_o) Six. The implication of the accepted Null hypothesis (h_o) Six is that there is no ability versus sex interaction effect on SAM. Therefore, the effects of ability are in the same direction for male and for female students.

Null hypothesis (h_o) Seven. Many implications are possible from the acceptance of Null hypothesis (h_o) Seven, that there is no method versus sex versus ability interaction. However the interactions tended to be in the same direction. That is, produce similar effects.

RECOMMENDATIONS

Development in Zambia could improve the quality of life of all Zambians. For more effective development, the country needs to develop a science and technology more adapted to her needs. Since mathematics is necessary for mastering the practice of science and technology, mathematics learning needs to be continuously improved. Towards this end, the following recommendations according to findings of the study hypotheses are suggested.

On the accepted finding of Null hypothesis (h_o) One that students' achievement in mathematics is influenced by ability, the following recommendations are made. Special measures need to be found to improve the mathematics achievement of the low ability students in schools. Classes might need to be streamed according to ability so that the less able students might receive special attention in their own classes. The attention might include use of instruction method found to be more effective with this group of students. Mathematics classes of high ability students could then be given more accelerated instruction to advance levels of mathematics needed for careers in advanced science and technology.

Ability was also found to be influenced by previous mathematics learning. More research studies are recommended on how the early home child rearing enviroment, pre-school and primary school mathematics teaching and learning might be improved to enhance later students' performance in mathematics.

Method of instruction did not show a significant relationship with SAM. A method versus sex interaction effect might have had some influence on the finding. Further studies of the relationship between method of instruction and sex with regard to mathematics achievement appear necessary.

In general, more Zambian studies appear necessary on the mathematics teaching and learning in schools. For otherwise, the production in adequate numbers of the necessary scientists, technicians and engineers necessary for national development might yet be not so near.

BIBLIOGRAPHY

Abiri, J. O. O. "The Educational Attitudes of some Nigerian Adolescent Grammar School Pupils" in West African Journal of Education. Vol. 10, No. 3, (October 1966:118-121).

Allport, G.W. "Attitudes" in Fishbein, M. (Ed.), Readings in Attitude Theory and Measurement. New York: Wiley , 1967.

Anastasi, A. Psychological Testing. London : Collier-MacMillan, 1968.

Ausubel, D.P. Educational Psychology: A Cognitive View. London : Holy Rinehart & Winston, 1968.

Bain, A.N. "An Investigation of the Arithmetical Skills of Fourth and Sixth Grade Low Achieving Readers". Unpublished Ed. D. Thesis, The John Hopkins University, 1982 abstract in Dissertation Abstracts International. Vol. 43, No. 2,(1982: 378A).

Banghart, F.W. "Group Structure, Anxiety and Problem Solving Efficiency" in Journal of Experimental Education. Vol. 28, No. 2, (December 1959 : 112 - 128).

Berry, J.W. "Temne and Eskimo Perceptual Skills" in International Journal of Psychology,. Vol. 1, No. 3, (1966 : 207-229).

Bieri, J. "Attitudes and Arousal" in Sherif, C.W. and Sherif, M. (Eds.), Attitudes, Ego-Involvement and Change. London : John Wiley, 1967.

Brigge, M.L. & Hunt, M.P. Psychological Foundations of Education. New York : Harper & Row, 1962.

Bloom, B.S., Krathwohl, D.R., and Bertram, B. Taxonomy of Educational Objectives. Hand Book 1., London : Longman, 1956.

Broudy, H.S. "Historical Examples of Teaching Methods" in Gage, N.L. (Ed.), Handbook of Research on Teaching. Chicago : Rand McNally & Co., 1963 : 1 - 43.

Bruner, J.S. The Act of Discovery" in Americam Psychologist. Vol. 31, No.1, (1961 : 21-32).

Bruner, J.S. "The Course of Cognitive Growth" in American Psychologist. 19, (1964 : 1 - 15a).

Bruning, J.L. & Kintz, B.L. Computational Handbook of Statistics. Chicago : Scott, Foresman & Co., 1968.

Bujam-Delgado, V.M. "A Study of the Relationships between Socio-economic Characteristics and Aspects of Mathematical Achievement of Primary School Children of Grades Four and Six in Costa Rica". Unpublished Ph.D. Thesis, Ohio State University, 1982.

Chikalanga, I.W. "Teaching Primary English in Zambia" in Zambia Educational Review. Vol. 4, No. 1 (January 1983 : 1 - 17).

Chishimba, M.M. "Observations on the English Medium Component of the Zambia Primary Course" in Zambia Educational Review. Vol. 2, No. 1, (December 1980 : 32 - 48).

Clemente, J.A. "A Comparison of Two Mathematics Curricula for Seventh Grade Metropolitan Caracas Students." Abstract of Unpublished Ed.D. Thesis in Dissertation Abstracts International. Vol. 43, No. 1, (1982 : 101A).

Cohen, L. Educational Research in Classrooms and Schools. London : Harper and Row, 1976.

Combs, A.W. The Professional Education of Teachers. Boston Mass. : Allyn and Bacon, 1965.

Copeland, R.W. How Children Learn Mathematics: Teaching Implications of Piaget's Research. New York : MacMillan, 1974.

Cronbach, L.J. and Furby, L. "How We Should Measure Change, Or Should We ?" in Psychological Bulletin Vol. 74, No. 1, (1970 : 68-80).

Davis, R.B. Discovery in Mathematics. (The Madison Project), California : Addison-Wesley, 1964.

Dawes, R.M. Fundamentals of Attitude Measurement. New York : John Wiley, 1972.

Dawson, J.L.M. "Cultural and Psychological Influences upon Spatial-Perceptual Process in West Africa" in International Journal of Psychology. Vol. 2, No. 2, (1967 : 115 - 128).

Deale, R.N. Assessment and Testing in the Secondary School. Schools Council Examination Bulletin 32. London : Evans-Methuen, 1975.

de Leeuw, L. "Teaching Problem Solving : Effect of Algorithmic and Heuristic Problem Solving Training in Relation to Task Complexity and Relevant Aptitudes" in Lesgold, A.M. et al., (Eds.), Cognitive Psychology and Instruction. New York : Plenum Press, 1978 : 269-275.

Dörner, D. "Theoretical Advances of Cognitive Psychology Relevant to Instruction" in Lesgold, A.M. et al., (Eds.), Cognitive Psychology and Instruction. New York : Plenum Press, (1978 : 231-252).

Duncan, C.P. "Recent Research on Human Problem Solving" in Psychological Bulletin. Vol. 56, No. 6, (1959:397-429).

Ferguson, R.D. "The Structure of Mathematics Anxiety in a Community College Setting". Abstract of an Unpublished Ph.D. Thesis, A. & M. University Texas, 1982 in Dissertations Abstracts International. No. 11, (May 1983: 3531 A).

Ferron, O.M. Developmental Psychology with Special Reference to the Third World. Lusaka: University of Zambia Collections, June 1980.

Fishbein, M. (Ed.), Readings in Attitude Theory and Measurement. New York : John Wiley, 1967.

Gagne, B.A. Teacher Education : A Special Investigation Report for Zambia Education Reform. Lusaka : Government Printer, 1975.

Gagne, R.M. The Conditions of Learning. New York : Holt, Rinehart and Winston, 1965.

Garofalo, J.F. "Simulteneous Synthesis, Behavior Regulation and Factor Structure of Arithmetical Performance." Abstract of Unpublished Ph.D. Thesis Indiana University 1982 in Dissertations Abstracts International. Vol. 43, No. 11, (May 1983 : 3531A).

Goldberg, S. "Infant Care, Stimulation and Sensory-Motor Development in a High Density Urban Area of Zambia" in Human Development Research Unit Report No. 15, Institute of Social Research, University of Zambia: 1970.

Gordon, I.J. Human Development from Birth through Adolescence. New York: Harper & Row, 1962.

Gronlund, N.E. Measurement and Evaluation in Teaching. New York : MacMillan, 1981.

Hoppers, W. "The Aftermath of Failure: Experiences of Primary School Leavers in Rural Zambia" in African Social Research Vo (June 1980:732).

Henderson, K.B. "Research on Teaching Secondary School Mathematics" in Gage, N.L. (Ed.), Handbook of Research on Teaching. Chicago: McNally & Co., 1963 : 1007-1031.

Holt, J. "Children are Sensitive to Space" in School Review. Vol. 82, No. 4, (August 1974 : 667 - 670).

Howson, A:G. (Ed.), Developments in Mathematics Education: Proceedings of the Second International Congress on Mathematics Education. London: Cambridge University Press, 1973.

Husén, T. International Study of Achievement in Mathematics: Volumes I and II. New York : John Wiley, 1967.

Insko, C.A. Theories of Attitude Change. New York: Meridith Publishing Co., 1967.

Isaacs, N. "Mathematics : The Problem Subject" in Land, Land, F.W. (Ed.), New Approaches to Mathematics Teaching. London : MacMillan, 1963 : 20 - 28.

Jahoda, M. and Warren, N. (Eds.), Attitudes. London : Penguin Books, 1966.

Kaniki, M.H.J. "Higher Education and Class Formation in Africa". Paper presented to : University of Zambia, History Staff Seminar, March 1982.

Kapambwe, G.M. "An Investigation into the Relationship Between Background and Scholarstic Achievement of a Group of Junior Secondary School Pupils in Zambia". Unpublished M.Ed. Dissertation, University of Zambia, Lusaka : 1980.

Kasanda, C.D. "Student Performance on Multiplication and Division of Decimal Examples Presented in Horizontal Format" in Zambia Educational Review. Vol. 6, No. 2, (June 1985 : 110 - 114).

Kerlinge, F.N. Foundations of Behavioral Research. New York : Holt, Rinehart & Winston, 1973.

Kingsley, S. "The Development of Zambian Children of Strategies for Doing Intellectual Work" in Human Development Research Unit Report. No. 24. University of Zambia, 1975.

Klausmeier, H.J. and Goodwin, W. Learning and Human Abilities. New York : Harper & Row, 1966.

Lawrence, L. and Sarvan, C. "Zambian English : An Inquiry" in Zambia Educational Review. Vol. 4, No. 1, (January 1983 : 27 - 39).

Likert, R. "The Method of Constructing an Attitude Scale" in Fishbein, M. (Ed.), Readings in Attitude Theory and Measurement. New York : John Wiley, 1967.

Lindgren, H.C. Educational Psychology in the Classroom. London : John Wiley, 1972.

Maslow, A.H. Motivation and Personality. New York:Harper and Row, 1954.

Maslow, A.H. Motivation and Personality New York : Harper and Row, 1970.

McClelland, D. C. The Achieving Society. Priceton New Jersey : van Nostrand, 1961.

Meece, J.L. "Sex Differences in Mathematics Achievement : Towards a Model of Academic Choice" in Psychological Bulletin. Vol. 91, No. 2, (March 1982 : 324 - 348).

Ming, E.M. "The Predictive Validity of the Junior Secondary School Leaving Examination (JSSLE) and the Quality of Selection to Form IV" in Ministry of Education, Psychological Services Report. No. 1, 1973.

Mulopo, M.M. "Effects of Traditional and Discovery Instructional Approaches on Learning Outcomes for Learners of Different Intellectual Development". Unpublished Ph.D. Thesis, The Pennsylvania State University, 1983.

Munro, D. "A Survey of Pre-school Children's Environments in a Lusaka Suburb" in Human Development Research Unit Report. No. 9, Institute of Social Research, Lusaka, University of Zambia, 1968.

Murphy, G. A Briefer General Psychology. New York : Harper and Row, 1935.

Murphy, L.B. "Childhood Experience in Relation to Personality Development" in Hunt, J. Mc V. Personality and the Behavior Disorder. New York : Ronald Press, 1944.

Newcomb, T.M. "On the Definition of Attitude" in Jahoda, M. and Warren, N. (Eds.), Attitudes. London : Penguin Books, 1966 : 22 - 24.

Nie, N.H., Hadlaihull, C., Jenkins, J.G., Steinbrenner, K. and Bent, D.H. Statistical Package for the Social Sciences (SPSS). New York : McGraw-Hill, 1975.

Njobe, M.W. "Effects of the Agricultural Science Curriculum, the School Environment and the Student's Home Socio-Economic Status on Attitudes Towards Careers in Agricultural Production". Unpublished M.Ed. Dissertation, The University of Zambia, Lusaka, 1983.

Nkwanga, E.B. "Zambia Primary School Children's Mathematics Attainment and Concept Development". Unpublished Ph.D. Thesis, London University, 1982.

Novak, J.D. "An Experimental Comparison of Conventional and Project Centred Method of Teaching a College General Botany Course" in Journal of Experimental Education. Vol. 26, (March 1958 : 217 - 230).

Okonji, O.M. "The Development of Logical Thinking in Pre-school Zambian Children" in Human Development Research Unit Report. No. 23, Lusaka : University of Zambia, 1972.

Oppenheimer, A.N. Questionnaire Design and Attitude Measurement. New York : Basic Books Publishers, 1966.

Peil, M. " The Influence of Formal Education on Occupational Choice" in Canadian Journal of African Studies. Vol. 7, No. 1, (1973 : 199 . 214).

Philip, H. "Mathematical Education in Developing Countries : Some Problems of Teaching and Learning" in Howson, A.G. (Ed.), Developments in Mathematical Education. London: Cambridge University Press, 1973.

Piaget, J. "Intellectual Evolution from Adolescence to Adulthood" in Human Development. Vol. 15, No. 1, (1972 : 124 - 141).

Republic of Zambia, Ministry of Education, Annual Reports. Lusaka : 1939 - 1980.

Republic of Zambia, Ministry of Education, Education Reform. Lusaka : Government Printer, 1977.

Republic of Zambia, Ministry of Education, Special Reports on Education Reform Special Investigation : Examination, Evaluation and Guidance. Lusaka: 1975.

Rosenberg, M.J. "Cognitive Structure and Attitudinal Affect" in Fishbein, M. (Ed.), Readings in Attitude Theory and Measurement. New York : John Wiley, 1967 : 325 - 331.

Roth, R.M. "The Role of Self Concept in Achievement" in Journal of Experimental Education. Vol. 27, (June 1959 : 265 - 281).

Rubenstein, R.N.P. "Mathematics Variables Related to Computational Estimation" (Abstract of an unpublished Ph.D. thesis Wayne State University 1982) in Dissertations Abstracts International. Vol. 43, No. 11, (May 1983 : 3531A).

Ryan, T.A. "Multiple Comparisons in Psychological Research" in Psychological Bulletin, Vol. 56, No. 1, (1959:26-47).

Sarason, S.B. and Gladwin, T. Anxiety in Elementary School Children. New York : John Wiley, 1960.

Scottish Mathematics Group (SMG), Modern Mathematics for Schools. Books 1 to 9. Glasgow : Blackie and Chambers.

Serpell, R. and Deregowski, J.B. "Teaching Pictorial Depth Perception in a Classroom Experiment" in Human Development Research Unit Report. No. 21, University of Zambia, 1972.

Shana, S.C.B. "Which Language ? A Brief History of the Medium of Instruction Issue in Northern Rhodesia" in Zambia Educational Review. Vol. 2, No. 1, (December 1980).

Sharma, R. "The Grade Seven Composite Examination : A Critique" in Ministry of Education, Psychological Service. Lusaka : August 1974.

Sharma, R. and Henderson, T. Numeracy at the Grade Three Level. Ministry of Education, Lusaka ; 1974.

Spearman, C.E. The Abilities of Man. New York : AMS Press 1970. (Reprint of a 1932 Edition).

Strachey, J. (Sigmund Freud) Short Accounts of Psycho-Analysis. London : Penguin Books, 1962.

Sunday Times of Zambia. Ndola : Printpak , 1981 - 1986.

Thomas, J.B. "School Organisation and Self Concept" in Durham Research Review. Vol. 7, No. 33, (1974 : 112 - 124).

Thurstone, L.L. in Vernon, P.E. The Structure of Human Abilities. London : Methuen & Co., 1971.

Times of Zambia. Ndola : Printpak, 1980 - 1986.

Tomlinson, B. "English Crash Course for Form One at Kaoma Secondary School" in Zambia Educational Journal. Lusaka, (January 1971 : 42 - 43).

United National Independence Party, The National Policies for the Decade 1985 - 1995. Lusaka : Govt Printer, 1984.

Vernon, P.E. The Structure of Human Abilities. London : Methuen & Co., 1950 and 1971.

Waddimba, E. Inservice Training of Primary School Teachers. Lusaka : University of Zambia, Special Collections, 1982.

Wiley, D.S. "Social Stratification and Religion in urban Zambia : An Exploratory Study in an African Suburb" Unpublished Ph.D. Thesis, Princeton Theological Seminar, 1971.

Willis, E.R. "Pupil Discovery versus Direct Instruction" in Journal of Experimental Education. Vol. 29, No. 3, (1961 : 271 - 281).

Witkin, H.A. "A Cognitive-Style Approach to Cross-Cultural Research" in International Journal of Psychology. Vol. 2, No. 4, (1967 : 233 - 250).

Wober, M. Psychology in Africa. London : International Africa Institute, 1975.

APPENDIX I

POST-TEST STUDENTS' ACHIEVEMENT IN MATHEMATICS

Instrument SAM Post-test. Time 80 minute

Instructions

1. Read these instructions carefully.
2. Do NOT write anything on this question paper.
3. There are TWO parts in this paper. Answer ALL questions in both parts.
4. For each question in Part I five options for an answer are given for you to choose ONE. Only one of the five options is correct. Work out on the rough wo paper provided which one of the five options is the BES correct answer. Then on your ANSWER sheet tick (✓) the letter with this answer.

   Example: 6 800 - 4 200 =

A. 2 500 B. 3 500 C. 2 400 D. 2 600 E. 11 000

The correct answer is 2 600, which is D. You would show this answer by ticking letter D on your answer sheet like this :

A B C D✓ E

5. In Part II, work out answers on the answer sheets provided. Rough work should be shown on the side of the answer sheet. Show all your working neatly.
6. Ensure that your name and class are written on all your answer sheets.

PART I

1. In the following sets, the set of odd numbers is :

   A. $\{1, 2, 3\}$ B. $\{0, 1, 3\}$ C. $\{2\}$
   D. $\{1, 3\}$ E. $\{0, 1, 2, 3\}$

2. The set containing the smallest number and the largest number from 35, 53, 39, 51, 33 is :

   A. {39, 33} B. {33, 53, 39} C. {51, 53} D. {39, 35, 33
   E. {35, 51, 33}

3. The set of whole numbers less than 4 is :

   A. {1, 2, 3} B. {0, 1, 3, 4} C {0, 1, 2, 3}
   D. {1, 2, 3, 4} E. {2, 3}

4. Which of the following sets are equal ?

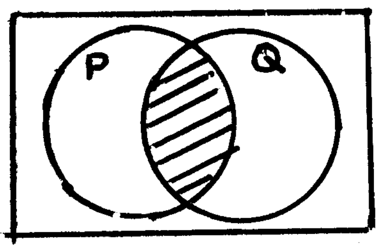
   (i) {a, b, c} (ii) {c, b, b, a} (iii) {a, a, b}
   (iv) {b, c, c}

   A. (i) and (ii) B. (i) and (iii) C. (iii) and (iv) D. (iv) and (i) E None of these.

5. If E is a universal set. P and Q are two sets such that $n(P \cup Q)' = 0$; $n(P') = 15$; $n(Q') = 5$ and $N(P \cup Q) = 30$ then $n(P \cap Q) =$

   A. 0 B. 15 C. 20 D. 30 E. 10

6. In this Venn diagram the shaded area represents



   A. $\emptyset$ B. $(P \cup Q)'$
   C. $(P \cap Q)'$ D. $P \cup Q$
   E. $P \cap Q$

7. Given that $P = \{1, 3\}$ $Q = \{1, 2, 3\}$ $R = \{1, 2, 3, 6\}$
   Which of the following statements is correct ?

   A. $P \subset Q \subset R$ B. $Q \subset P \subset R$ C. $R \subset Q \subset P$ D. $P \subset R \subset Q$ E. None of these.

8. $K = \{-1, 0, 1, 2\}$ $L = \{0, 1, 2\}$ $M = \{-2, -1, 0\}$
   N $\{-1, 0\}$ Which of the following is true ?

   A. $L \cap K = K \cup N$ B. $L \cup N = L \cap K$
   C. $K \cup N = K \cap M$ D. $K \cap M = M \cap N$
   E. $L \cup N = K \cap N$

9. A survey of 1300 homes in Lusaka gave the results expressed by the following sets : M = {850 families owned a car each.} N = {1150 families owned a television each.} Then $n(N \cap M') =$

   A. 450 B. 400 C. 50 D. 1150 E. 350

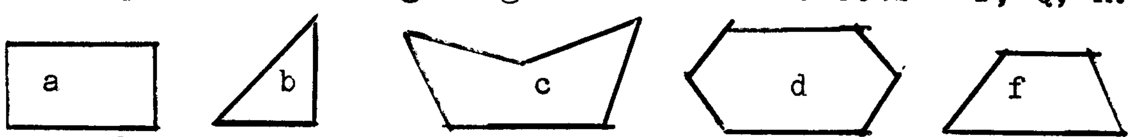
PART II

10. List the following sets :
   (a) {Numbers which divide into 24}
   (b) {Squares of the first six whole numbers .}

11 . Describe these sets :
   (a) {January, June, July}
   (b) {President, Prime minister and cabinet ministers, Central committee members in Zambia.}

12. Describe the following set in words :
   {0, 1, 2, 3, 4, 5, ...}

13 . Group the following diagrams into three sets : P, Q, R.



14. $S = \{3, 6, 9, 12\}$ Form new sets as follows :
   (a) Set C by dividing each member of S by 3
   (b) Set D by adding elements of S TWO at a time in ALL possible ways.

15. List the set of total scores possible when two dice are thrown together.

16. If $E = \{1, 2, 3, 4, 5, 6, 7, 8\}$ $A = \{2, 4, 6, 8\}$ and $B = \{1, 2, 3, 4, 5\}$ Complete:
   (a) $A \cap B =$ --- (b) $B' =$ --- (c) $(A \cup B)' =$ (d) $(A')' =$

17. Let A and B be two sets.
   (a) Is there <u>another</u> set Y with elements such that $B \cup Y = B$
   (b) Is there another set X with elements such that $B \cap X = B$

18. If $A = \{1, 2, 3, 4\}$ $B = \{2, 3, 4, 5, 6,\}$ and $C = \{2, 4\}$ which of the following are TRUE ?
   $B \subseteq A$; $B \subseteq C$; $C \subset B$; $C \not\subset A$; $\emptyset \subset B$

19. Are the following statements True or False ?

(a) If $A \subseteq B$ and $B \not\subseteq C$ then $A \not\subseteq C$

(b) $3 \in \{$set of Real numbers$\}$

(c) $2 \notin \{$set of prime numbers$\}$

20. If $A = \{1, 2, 3, 4, 5\}$, $B = \{3, 6, 9, \ldots 99\}$ and $C = \{5, 10, 15, \ldots\}$ In (a) to (c) Copy and complete the following by inserting the symbol for 'element of' or 'not element of' in the spaces indicated by dotted lines.

(a) 5 ... B (b) 15 ... C (c) 300 ... C

(d) Which element of A also belongs to C ?

21. Which of the following are 'empty sets' ?

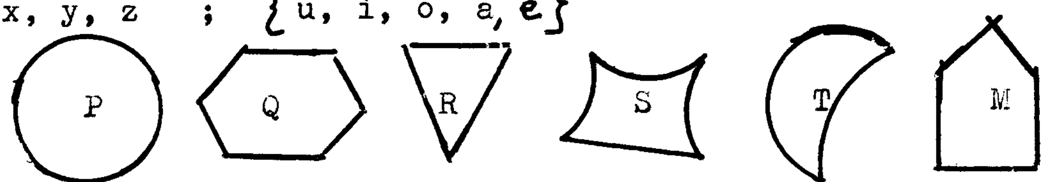
(a) {Odd numbers which are divisible by 2}

(b) {Even numbers which are divisible by 5}

22. Write down any pairs of equal sets from the following:

{2, 6} ; {4, 2, 6} ; {vowels in the English alphabet} ; x, y, z ; {u, i, o, a, e}

23.



The above figures shows a set S of shapes with straight and curved sides. Use the capital letter on the shapes to list the members of the following sets.

(a) The subset of S whose members have more than five straight sides.

(b) The subset of the mebers of S with exactly two curve sides.

(c) The subset of members of S with eight straight sides.

24. Say whether each of the following is true or false :

(i) $\{a, b, c\} \subset \{a, b, c\}$ (ii) $\{\ \} \subset \{a, b, c\}$

25. $S = \{3, 4, 5, 6, 7, 8\}$, $T = \{5, 7, 9, 11\}$. List the following subsets of S :

(a) Its members are divisible by 3

(b) Its members are members of S which are 3 less than members of T.

26. List all the subsets of each of the following :

(a) $\{p, q\}$ (b) $\{p, q, r, s\}$

27. Draw sketches of a cuboid, a cylinder, a cone and a sphere.

28. If A = {cuboids, cylinders, cones, spheres}
List the following subsets of A :

(a) The set of solids which have no corners.

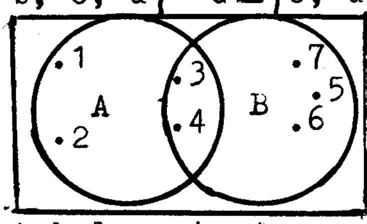
(b) The set of solids which have at least one flat surface.

29. Which of the following are True ?
(a) $2 \subset \{1, 2, 3\}$ (b) $2 \subset \{1, 2, 3\}$ (c) $2 \in \{2\}$

30. State a possible universal set for each of the following :
(a) {copper, silver, gold} (b) {3, 5, 7}
(c) {cylinder, sphere}

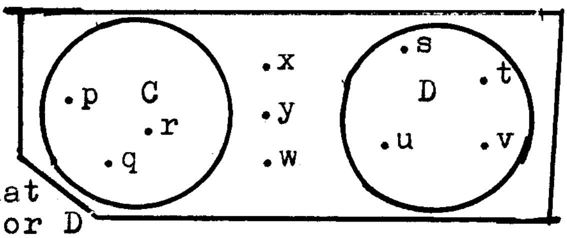
31. Illustrate each of the following by a Venn diagram:
E = {a, b, c, d, e, f} ; F = {a, b, c, d} G = {c, d, e}

32. From the Venn diagram on the right, list the mebers of the following sets :



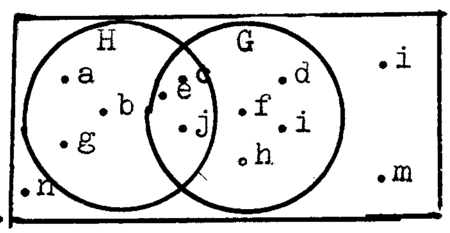
(a) Set B
(b) set of elements that do not belong to A.

33. From the diagram on the right list members of the following sets:



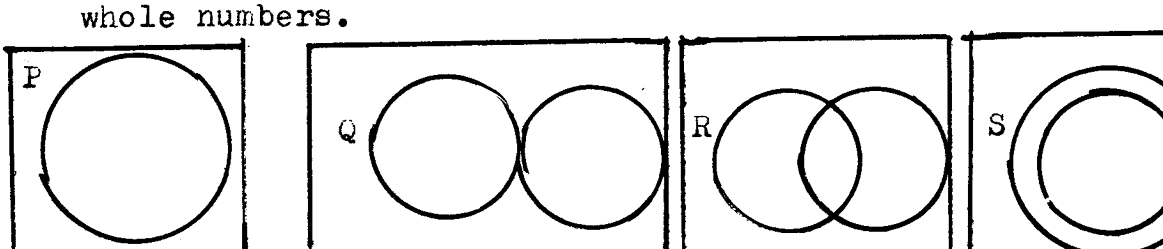
(a) set D
(b) set of elements that belong to either C or D

34. In the figure on the right
E = {pupils selected from a senior class.}
H = {pupils who like History}
G = {pupils who like Geography}



Each letter represents a pupil. (a) How many pupils like Geography ? (b) How many pupils like History but not Geography ? (c) How many pupils like neither History nor Geography ?

35. Which of the Venn diagrams below illustrate the pairs of sets following the diagrams ? E is the set of whole numbers.



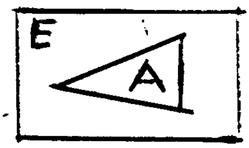
(a) A={even numbers} , B = {odd numbers}
(b) D={multiple of 2} F = {multiples of 4}

36. If D = {prime numbers less than 12} F={even numbers less than 12} W = {whole numbers} List :
(i) D ⋂ W (ii) D ⋃ F

37. If E={letters of the alphabet}, Q= {b, c, d}, R={d, e, f}, P={a, b, c, d, e, f}, List sets :
(i) Q ⋂ R (ii) P ⋂ R

38. If E={1, 2, 3, 4, 5, 6} B={1, 3, 4, 5} C = {5}
(a) List the sets (i) B ⋂ C (ii) E ⋂ B
(b) Show these interactions in separate Venn diagrams The use of shading or colouring will help.

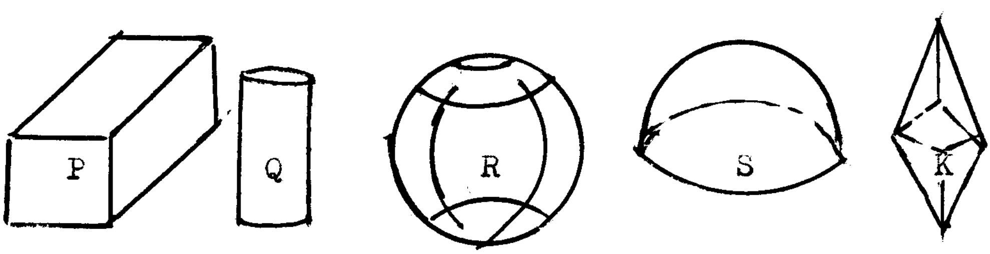
39. Copy the diagram on the right and shade the region that represents the intersection of A and E



40. Of 25 girls, 18 like pop music, 13 like classical music and 10 like both.
(a) Illustrate these facts in a Venn diagram.
(b) How many girls like neither pop nor classical music ?

41. If there are 10 members in set A, 7 members in set B and 4 members in the set A ⋂ B, How many members of A are NOT members of B ?

42. Which of the shapes below have:
(a) only curved edges.
(b) flat and curved surfaces in the same shape ?

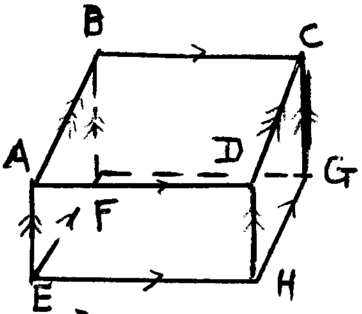


43. A wall is made of bricks 20 cm long, 10 cm broad and 6 cm high.

(a) Sketch the brick and mark in its dimensions.

(b) State the length and breadth of each of the other faces

44. The figure on the right shows a cuboid with all its corners named. Edges which point in the same direction are shown by parallel lines.



Name : (i) three lines parallel to BC.
(ii) three lines parallel to AE.
(iii) another set of four parallel lines.
(iv) Why are BF, EF, and FG shown dotted ?

45. If E $\{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$, and
$A = \{2, 3, 4, 5, 6\}$, $B = \{3, 5, 6, 7, 8, 9\}$,
C $\{4, 5, 6, 9, 10\}$, are subsets of E.

(a) List the sets $B \cap C$ and $A \cap B \cap C$

(b) Illustrate by a Venn diagram.

46. Which elements named in the list are not members fof the set described ?

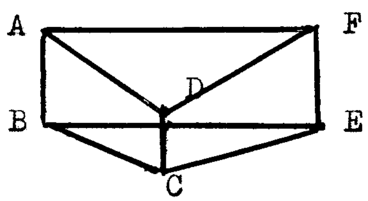
The set of odd numbers from 0 through to 10.
$\{3, 6, 7, 11, 0\}$

47. Given $E = \{1, 2, 3, \ldots\}$ and $M = \{1, 3, 5, 7, 9, \ldots\}$
Write down M'

48. If $E = \{1, 2, 3, 4, 5, 6, 7, 8\}$, $P = \{2, 5, 7, 8\}$,
$Q = \{1, 8\}$ List (i) $P \cap Q'$ (ii) $Q' \cup P$
(iii) $Q' \cap P'$

49. Given $E = \{a, e, i, o, u\}$ $P = \{a, i\}$ List
(i) P' (ii) $P \cap P'$

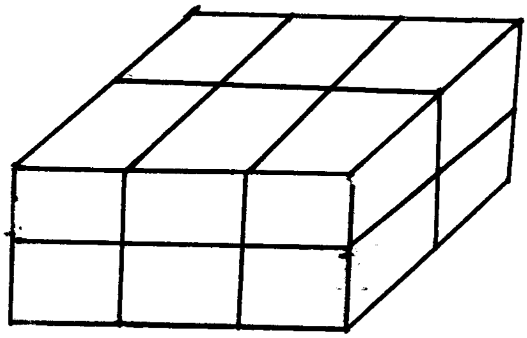
50. In the figure on the right,



How many :

(i) faces are there ?
(ii) faces are triangular ?
(iii) sets of parallel edges ?
(iv) angles are formed by the lines meetings at E

51. The figure below is a large cuboid divided into smaller cuboids. How many of these smaller cuboids are there ?



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SCORING SCHEME FOR POST-TEST STUDENTS' ACHIEVEMENT IN MATHEMATICS

(Points in brackets)

1. D
2. B
3. C
4. A
5. E
6. E
7. A
8. D
9. E

(1 point each) (

10. a) $\{24, 12, 4, 3, 8, 6, 2, 1\}$ (2)
    b) $\{0, 1, 4, 9, 16, 25\}$ (2)

11 a) Names of months in a year begining with J (2)
   b) Members of the Zambian government (2)

12. a) Set of whole numbers (1)
    b) $P = \{d, c\}$ $Q = \{f, a\}$ $R = \{b\}$ (1 each)

13. a) Set $C = \{1, 2, 3, 4\}$ (1)
    b) Set $D = \{9. 12, 15, 18, 21\}$ (2)

14. $\{2, 3, 4, 5, 6, 7, 8, 9, 11, 12\}$ (3)

15. a) $A \cap B = \{2, 4\}$ (1)
    b) $B' = \{6, 7, 8\}$ (1)
    c) $(A \cup B)' = \{7\}$ (2)
    d) $(A')' = \{2, 4, 6, 8\}$ (2)

16. a) Yes $Y = B$ (1) b) Yes $X = B$ (1)

17. $C \subset B$ (1) $C \in A$ (1) $\emptyset \subset B$ (1)

18. a) True (1) b) True (1) c) False (1)

19. a) $\notin$ (1) b) $\in$ (1) c) $\in$ (1) d) 5 (1)

20. a) Empty set (1) b) not empty set (1)

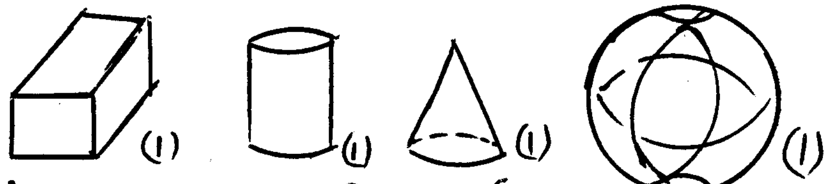
21. $\{$Vowels of the English Alphabet$\} = \{u, e, i, o, a\}$ (2)
    (if an equal pair is given -1 point)

22. a) $\{Q\}$ (1) b) $\{T\}$ (1) c) $\emptyset$ (1)

23. i) T (1) ii) T (1)

24. a) $\{3, 6\}$ (1) b) $\{4, 6, 8\}$ (1)

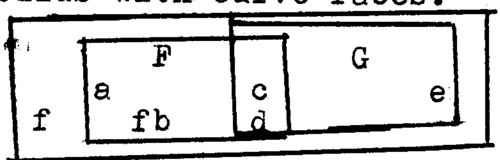
25. a)) $\emptyset$, (1), $\{p\}$ (1) , $\{q\}$ (1), $\{p, q\}$ (1)
    b) $\emptyset$, $\{p, Q q, r, s\}$; $\{p\}$; $\{q\}$; $\{r\}$; $\{s\}$; $\{p, q\}$; $\{p, r\}$; $\{p, s\}$; $\{q, r\}$; $\{q, s\}$; $\{r, s\}$; $\{p, q, r\}$; $\{p, r, s\}$; . $\{q, r, s\}$; (8) must at least name two for a mark.

26. 

27. a) {cylinder, spheres} b) {cyliders, cuboid cones}
(1 point for each set)

28. (a) True (b) True (c) True (1 point each)

29. (a) precious minerals (1) (b) 2 < prime numbers ≤ 7
(c) solids with curve faces.

30. 

(3)

31. B = {3, 4, 5, 6, 7} (2) (b) A' = {5, 6, 7} (2)

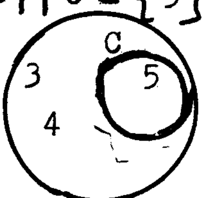
32. Set D = {s, t, u, v} (2) (b) (C ∪ D) = {p, r, q, s, t, u, v}
(2)

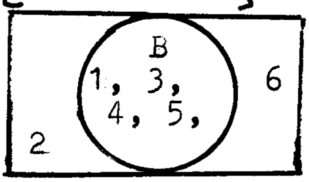
33. (a) 7 (1) (b) 3 (1) (c) 3 (1)

34. (a) Q (1) (b) S (1) (1)

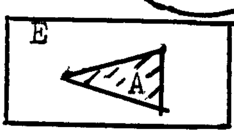
35. (i) D ∩ W (1) {2, 3, 5, 7, 11} (1)
(ii) D ∪ F = {2, 3, 4, 5, 6, 7, 8, 10, 11}

36. (a) i) {d} (1) ii) {d, e, f} (1)

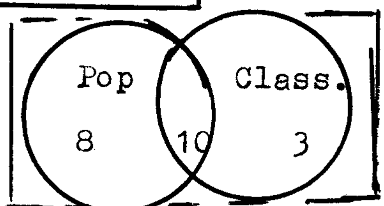
37. (a) i) B ∩ C = {5} (1) ii) {1, 3, 4, 5} (1)
(b) i) 

(2) ii) 

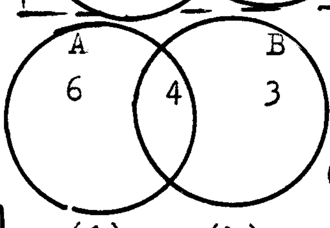
(2)

38. 

(1)

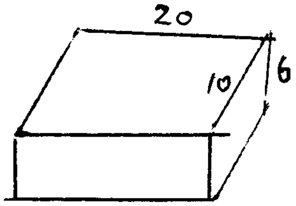
39. (a) 

(3) (b) 4 (1)

40. (a) 

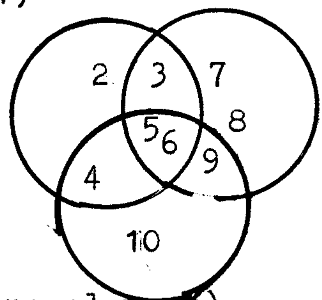
(1) (b) n(A) not members of B = 6 (2)

41. (a) {Q, S} (1) (b) {Q, S} (1)

42. (a) 

(1) b) 10 x 6 (1) , 20 x 6 (1)

43. i) AD, FG, EH, (1) ii) BF, CG, H DH (1)
iii) Ab, DC, HG, EF. (1)
iv) Not visible from front. (1)

44. a) $B \cap C = \{5, 6, 9\}$ (2) b) 

(3)

b) $A \cap B \cap C = \{5, 6\}$ (2)

45. $\{0, 6, 11\}$ (2) (-1 for missing element)

46. $M' = \{2, 4, 6, \ldots\}$ (2) $P = \{2, 5, 7, 8\}$

47. i) $P \cap Q' = \{2, 5, 7, 8\}$ (1) ii) $Q' \cup P = \{2,4,3,5,6,7,8\}$ (2)
iii) $Q' \cap P' = \{3, 4, 6\}$ (2)

48. i) $P' = \{e, o, u\}$ (2) ii) $\emptyset$ (1)

49. i) 5 (1) ii) 2 (1) iii) 4 (1)

50. 12 (1)

(Total points 150).

APPENDIX II

PRETEST : STUDENTS' ACHIEVEMENT IN MATHEMATICS

Instrument SAM Pretest. Time 80 minutes.

Instructions

1. Read these instruction carefully.

2. Do NOT write anything on this question paper.

3. There are TWO parts in this paper. Answer ALL questions in both parts.

4. For each question in Part I, five options for an answer are given for you to choose ONE. Only one of the five options is correct. Work out, on the rough work paper provided, which one of the five options is the BEST correct answer. Then on your ANSWER sheet tick (✓) the letter with this answer.

   Example: 6 800 - 4 200 =

A. 2 500 B. 3 500 C. 2 400 D. 2 600 E. 11 000

The correct answer is 2 600, which idis D. You would show this answer by ticking letter D on your answer sheet like this :

A B C D✓ E.

5. In Part II, work out the answers on the answer sheets provided. Rough work should be shown on the side of answer sheet. Show all your working neatly.

6. Ensure that your name and class are written on all your answer sheets.

PART I

1. Which one of the following is a set of prime numbers less than five ?

   A. $\{0, 1, 2, 3, 4, 5\}$ B. $\{0, 1, 2, 3, 4\}$ C. $\{1, 2, 3\}$
   D. $\{2, 4\}$ E. $\{2, 3\}$

2. Which one of the following is a set of whole numbers greater than 10 but less than 15 ?

A. $\{11, 12, 13, 14, 15,\}$ B. $\{10, 11, 12, 13, 14\}$
C. $\{11, 12, 13, 14\}$ D. $\{10, 11, 12, 13, 14, 15\}$
E. $\{11, 13\}$

3. Which of the following sets are equal ? 1. $\{4, 5, 6\}$
2. $\{5, 6, 7\}$ 3. $\{6, 4, 5\}$
A: 1 and 3 B. 1 and 2 C. 1 and 2 and 3 D. 3 and 2
E. None of them .

4. Which of the following statement is true ?
A. $4 \in \{5, 7, 3\}$ B. $7 \notin \{4, 7, 2\}$ C. $\{a, b\} \in \{b, c, d\}$
D. $\emptyset \in \{2, 3\}$ E. None of these.

5. Given that $X = \{-2, 0\}$ $Y = \{0, 2\}$ Then $X \cap Y =$
A. $\{-2, 0, 0, 2\}$ B. $\{-2, 0, 2\}$ C. $\{0\}$ D. $\{\}$ E $\{-2, 2\}$

6. Given that P and Q are sets and $n(P) = 8$, $n(Q) = 5$
$n(P \cap Q) = 3$. Then $n(P \cup Q) =$
A. 3 B. 8 C. 10 D. 13 E. 16

7. If $E = \{2, 3, 4, 6, 7, 8, 10, 11, 12, 17, 21\}$
$P = \{2, 4, 6, 7, 8, 12, 21\}$
$Q = \{2, 3, 10, 11, 17\}$
$S = \{4, 6, 7, 8, 12, 21\}$
$R = \{3, 10, 11, 17\}$ Then $P' =$
A. P B. Q C. R D. S E. E

8. Given that $P = \{\text{multiples of } 2\}$, $Q = \{\text{multiples of } 4\}$
$R = \{\text{multiples of } 3\}$. Then a set which contains <u>all</u> the elements of the above sets is :
A. $Q \cup R$ B. $P \cup R$ C. $P \cup (R \cap Q)$ D. $P \cap (R \cup Q)$
E. $P \cap R \cap Q$

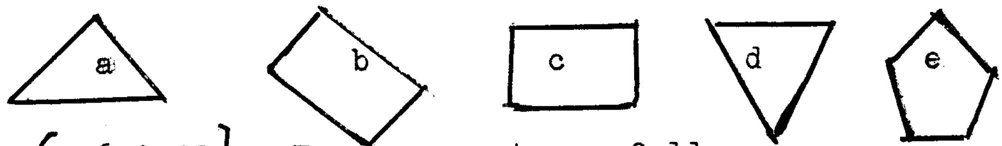
9. A survey of 1300 homes in Lusaka gave the results expressed in the following sets.
$M = \{$Set of 850 families owning a car each$\}$
$N = \{$Set of 1150 families owning a television each$\}$
Families owning both a car and a television set were 800 . Then $n(M \cup N)$ equals : A 1300 B. 1150
C. 1200 D. 1250 E. 2000

PART II

10. List the following sets :
    (a) numbers obtained by doubling 5, 7, 10, 14 .
    (b) last five letters of the English Alphabet.

11. Describe these sets in words :
    (a) $\{0, 2, 4, 6, 8, 10\}$ ~~(b)~~
    (b) $\{423, 432, 243, 234, 342, 324\}$ (c) $\{0, 3, 6, 9, 12$

12. Group the following diagrams into three sets P, Q and R.



13. $S = \{3, 6, 9, 12\}$ Form new sets as follows :
    (a) Set P by multiplying each member of S by 2.
    (b) Set Q by adding 1 to each member of S.

14. List the set of total score possible when numbers on pairs of cards drawn a pair at a time from five cards numbered 1, 2, 3, 4, 5 are added.

15. If $E = \{1, 2, 3, 4, 5, 6, 7, 8\}$ and $A = \{2, 4, 6, 8\}$
    $B = \{1, 2, 3, 4, 5\}$ Copy and complete :
    (a) $A \cup B =$ .. (b) $A' =$ .. (c) $(A \cap B)' =$ (d) $(B')' =$

16. Let A and B be two sets. Are there other sets X and Y with elements such that : (Write Yes or No)
    (a) $A \cap X = A$ (b) $A \cup Y = A$.

17. If $A = \{1, 2, 3, 4\}$, $B = \{2, 3, 4, 5, 6\}$, $C = \{2, 4\}$
    Which of the following are true ? (a) $A \subseteq B$
    (b) $C \subseteq B$, (c) $C \subseteq A$, (d) $C \subset A$, (e) $B \subset C$,

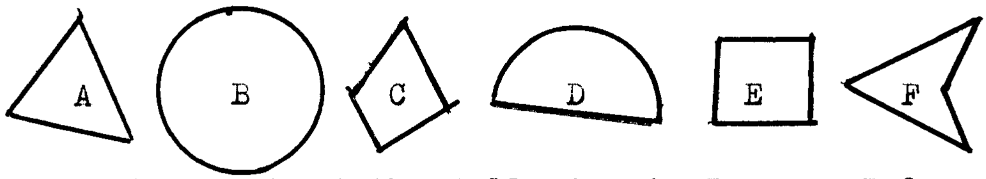
18. Are the following statements true or false ?
    (a) If $A \subseteq B$ and $B \subseteq C$. Then $A \subseteq C$
    (b) 9 is an element of a set of odd numbers.
    (c) $4 \notin \{\text{odd numbers}\}$

19. If $A = \{1, 2, 3, 4, 5\}$, $B = \{3, 6, 9, \ldots 99\}$,
    $C = \{5, 10, 15, \ldots\}$ Copy and complete the following by inserting or in the spaces of the dots.
    (a) 5 ... A (b) 15 ... B (c) 300 ... B
    (d) Which element of A also belongs to B ?

20. Which of the following are empty sets ?
 (a) Set of students in your class who are less than six years old.
 (b) Set of prime numbers between 13 and 17.

21. Write down pairs of equal sets from sets given below.
 $\{2, 4, 6\}$; $\{x, y\}$; $\{y, x\}$; $\{1, 4, 9, 6\}$; $\{1, 3, 5, 7$

22. The figure shows a set S of shapes with straight and curved sides. Use the capital letters on the shapes to list the members of the following subsets of S
 (a) The subset P of the members of S with exactly four straight sides.
 (b) The subset Q with only one curved side.
 (c) The subset R with more than two curved sides.



23. Say whether each of the following is True or False.
 (a) $\{2, 3, 4\} \subset \{2, 3\}$
 (b) $\{x, y\}$ has four subsets.

24. $S = \{3, 4, 5, 6, 7, 8\}$ $T = \{5, 7, 9, 11\}$ List the following subsets of S.
 (a) Subset P whose members are greater than 8.
 (b) Subset Q whose members are members of S and also members of T.

25. List all the subsets of each of the following.
 (a) $\{p\}$ (b) $\{p, q, r\}$

26. Draw sketches of a cuboid, a cylinder, a cone and a sphere.

27. If A = {cuboids, cylinders, cones, spheres}
 List the following subsets of A.
 (a) The set of solids which have six faces.
 (b) The set of solids which have two curved surfaces.

28. Which of the following are true ?
 (a) $2 \in \{1, 2, 3\}$ (b) $2 \subset \{1, 2, 3\}$ (c) $\{2\} \subset \{2\}$

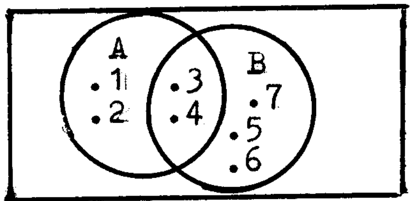
29. State the possible universal set E for each of the following.
(a) {carrot, cabbage, rape}, (b) {pen, pencil, paper}
(c) { cube, cuboid }

30. Illustrate each of the following by a Venn diagram
E = {1, 2, 3, 4, 5, 6}, P = {1, 2, 3}, Q = {4, 5}

31. From the figure below, list the members of the following sets:

(a) Set A

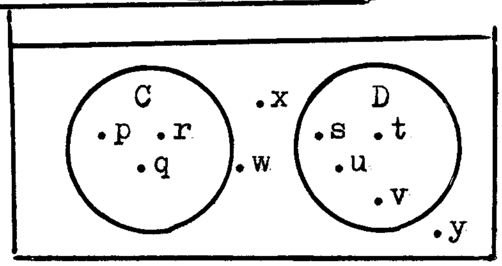
(b) Set of elements that belong to either A or B.



32. From the figure on the right, list members of the following sets.

(a) Set C

(b) The set of elements that do not belong to C and to D.

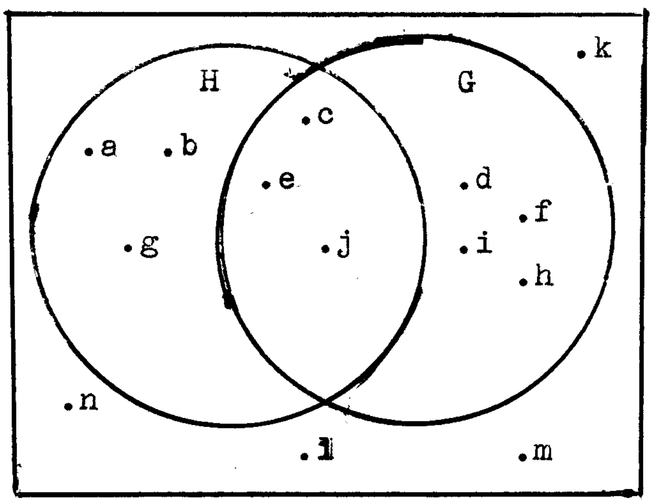


33. In the figure on the right, E = {pupils selected from a senior class}
H = {pupils who like history.}
G = {pupils who like geography}
Each letter represents a pupil.

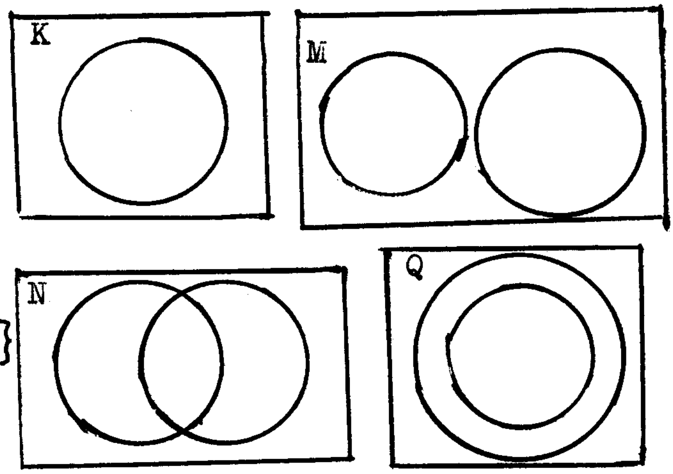
(a) How many pupils like history ?

(b) How many pupils like both history and geography ?

(c) How many pupils like geography but not history ?



34. Which of these Venn diagrams on the right illustrate the pairs of sets given below, where E is the set of whole numbers ?



(a) A={even numbers.}

(b) P={prime numbers,}

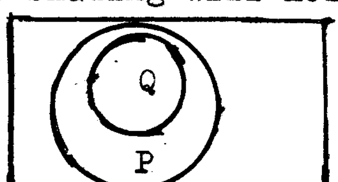
(b) S ={numbers divisible by 2 and by 5}
T ={numbers divisible by 10}

35. If D ={prime numbers less than 12}
F ={even numbers less than 12}
W ={whole numbers.} List D ⋂ F

36. E={letters of the alphabet}, P= {a, b, c, d, e, f}, Q={b, c, d}, R={d, e, f}, S={f}. List the sets:
(i) P ⋂ Q (ii) R ⋂ S

37. E ={1, 2, 3, 4, 5, 6}, A={1, 2, 3, 4}, B={3, 4, 5}, C={5} (a) List the sets (i) A ⋂ B (ii) A ⋂ C
(b) Show these intersections in separate diagrams. The use of shading will help.

38. Copy the diagram on the right and shade the region that represents the intersection of P and Q.

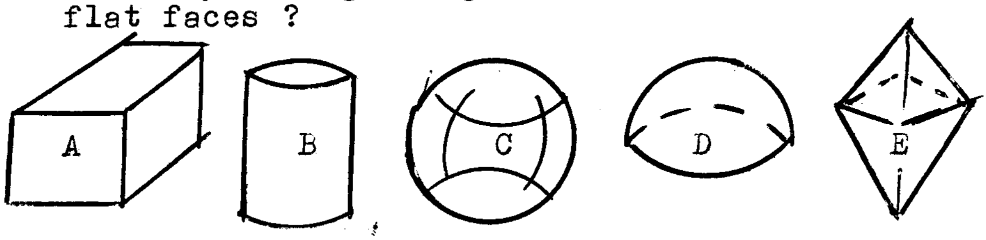


39. In a group of boys, 15 liked ice cream, 20 liked sweets, and 12 liked both.
(a) *Illustrate these facts in a Venn diagram.*
(b) How many boys are in the group ?

40. *There are 20 girls in a certain class. 16 of them study physics, 14 study chemistry and 12 study both physics and chemistry.*
(a) Draw a suitable Venn diagram. (b) Deduce the number of girls in the class who study neither physics nor chemistry.

41. *E = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}, A ={2, 3, 4, 5, 6}*
B ={3, 5, 6, 7, 8, 9}, C ={4, 5, 6, 9, 10}, are subsets of E. List (i) A ⋂ B (ii) C ⋂ A

42. Which of the shapes in the figure below have : (a) only straight edges (b) both curved and flat faces ?

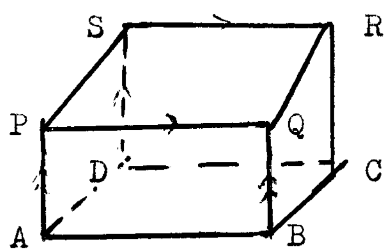


43. A wall is made of bricks 22 centimetre long, 11 cm broad and 7 cm high.

(a) Sketch the brick and mark its sides.

(b) How many faces measure 22 cm by 11 cm ?

44. The figure on the right shows a cuboid with all its corners named. Edges which point in the same direction are shown by parallel lines.



(a) Which three lines are parallel to AB ?

(b) Which three lines are parallel to BC ?

(c) Name another set of parallel lines.

(d) Why are AD, DC, and DS shown in dotted lines ?

45. Which elements named in the list are not members of the set described.

The set of even numbers from 0 through to 10.

$\{8, 5, 12, 3, 4\}$

46. Given $E = \{0, 1, 2, 3, 4, 5, \ldots\}$ and $M = \{4, 5, 6, \ldots\}$ Write down M'

47. Given $E = \{1, 2, 3, 4, 5, 6, 7, 8\}$ and $P = \{2, 5, 7, 8\}$; $Q \{1, 8\}$. List

(i) P' (ii) $P' \cap Q$ (iii) $Q' \cup P'$

48. If $E = \{1, 2, 3, 4, 5\}$ and $P = \{2, 4\}$ List

(i) P' (ii) $P \cap P'$

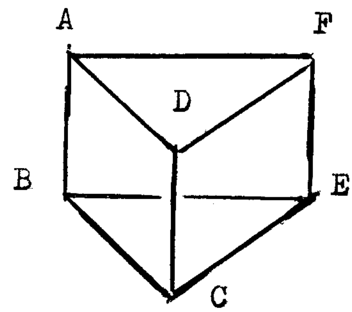
49. In the figure on the right how many :

(i) corners are there ?

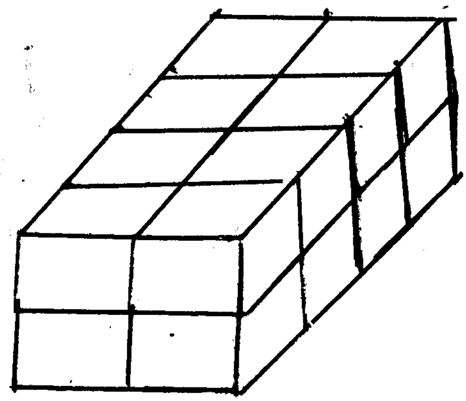
(ii) edges are there ?

(iii) faces bounded by four sides each ?

(iv) angles are formed by the lines meeting at A ?



50. The figure on the right is a large cuboid divided into smaller cuboids. How many of these smaller cuboids are there ?



SCORING SCHEME FOR PRE-TEST OF STUDENTS' ACHIEVEMENT IN MATHEMATICS

(Points in brackets)

1.	E	4.	D	7.	C
2.	C	5.	C	8.	B
3.	A	6.	C	9.	C

(All 1 point each)

10. (a) {10, 14, 20, 28} (2) (b) {v, w, x, y, z} (2)

11. (a) Set of whole numbers divisible by 2 (1)
    (b) Set of numbers of three digits formed by using 2, 3, and 4 for each number. (2)
    (c) whole numbers divisible by 3 and not more than 12. (2)

12. P = {three sides} (1) Q = {five sides} (1)
    R = {four sides} (1)

    OR

    P as triangles a, and d ; Q as pentagon or polygon e
    R as quadrilaterals b and c.

13. (a) P = {6, 12, 18, 24} (2) (b) Q = {4, 7, 10, 13} (2)

14. {23, 3, 4, 5, 6, 7, 8, 9, 10} (2)

15. (a) $A \cup B$ = {1, 2, 3, 5, 6, 8, 4} (3)
    (b) A' = {1, 3, 5, 7} (2)
    (c) $(A \cap B)'$ = {1, 3, 5, 6, 7, 8} (3)
    (d) (B')' = {1, 2, 3, 4, 5} (3)

16. (a) yes if X is contained in A (1) (b) Yes if Y = A (1)

17. 'a' (1) 'b' and 'c' (1)

18. (a) True (2) (b) True (1) (c) True (1)

19. (a) $\in$ (1) (b) $\in$ (1) (c) $\notin$ (1)
    (d) 3 (1)

20. (a) ∅ (1) (b) ∅ (1)

21. {x, y} = {y, x} (1)

22. (a) P = {C, E, F} (2) (b) Q = {D, B} (2) (c) R = { } (2)

23. (a) false (10 (1) (b) True (1)

24. (a) $P = \emptyset$ (1) (b) $Q = \{5, 7\}$ (1)

25. (a) $\emptyset$ (1) , $\{P\}$ (1)

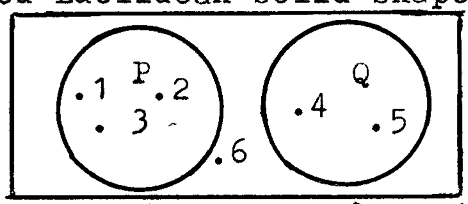
(b) $\emptyset$; $\{p\}$; $\{q\}$; $\{r\}$; $\{p,q\}$; $\{p,r\}$
$\{p,q,r\}$; $\{r,q\}$ (1 point per subset)

26. 1 point for a reasonable, even free hand, drawing of each

27. (a) {cuboids} (1) (b) $\emptyset$ (1)

28. (a) True (b) True (c) True (1 point each)

29. (a) E is set of {human edible vegitables} (2)
(b) E is {'stationary} (1) (c) E is {six plane faced Euclidean solid shapes}

30. 

(3)

31. (a) $A = \{1, 2, 3, 4\}$ (2) (b) {1, 2, 3, 4, 5, 6, 7
(3)

32. (a) $C = \{p, r, q\}$ (2) (b) $\{x, w, y\}$ (2)

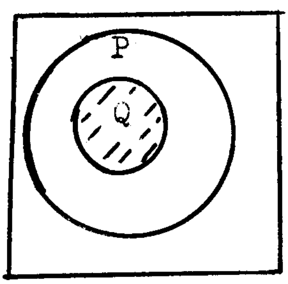
33. (a) 6 (1) (b) 3 (1) (c) 4 (1)

34. (a) N (1) (b) Q (1)

35. $D \cap F = \{2\}$ (1)

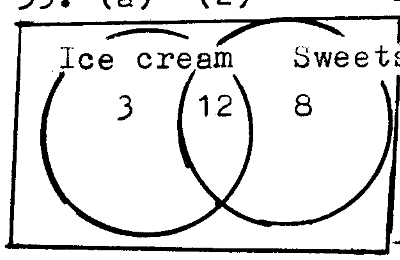
36. (i) $P \cap Q = \{b, c, d\}$ (2) (ii) $R \cap S = \{f\}$ (1)

37. (i) $A \cap B = \{3, 4\}$ (1) (ii) $A \cap C = \emptyset$ (1)

38. 

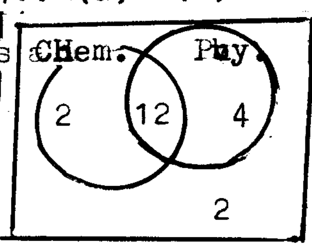
(1)

39. (a) (2)



39. (b) 23 boys (1)

40. (a) (2)



40. (b) 2 (1)

41. (i) $A \cap B = \{3, 5, 6\}$ (2) (ii) $C \cap A = \{4, 5, 6\}$ (2)

42. (a) A and E (1) (b) B and D (1)

43. (a) Sketching (1) , marking (1) (b) 4 (1)

44. (a) DC, PQ, SR (2) (c) {AP, DS, CR, BQ} (3)
(b) QR, PS, AD (2) (d) not visible (1)

45. $\{5, 3, 12\}$ (2)

46. $M' = \{0, 1, 2, 3\}$ (2)

47. (i) $P' = \{1, 3, 4, 6\}$ (1) (ii) $P' \cap Q = 1$ (1)
(iii) $Q' \cup P' = \{1, 2, 3, 4, 5, 6, 7\}$ (2)

48. (i) $P' = \{1, 3, 5\}$ (2) (ii) $P \cap P' = \emptyset$ (1)

49. (i) 6 (1) (ii) 9 (1) (iii) 3 (1)
(iv) 3 (1)

50. 16 (1)

(Total points 150)

APPENDICES III AND IV

(in one instrument)

Instrument Main Study: Motivation/Attitude Scales. Time: ½hr.

Student's No. ....

The purpose of this quaetionnaire is to find out more about some of the problems that might be affecting students' learning of mathematics. We could then be able to suggest ways of helping students overcome these problems. Towards this end, the statements which follow seek your opinion about some aspects of mathematics. There are no correct nor wrong answers to these statements. Answers are likely to differ according to how different students feel about learning mathematics. The answers you make to the state-ments will NOT be used as scores for your school report. Infact your school will not even be told what answers you gave. To be sure about this DO NOT write your name on this questionnaire. Please therefore answer ALL the statements without any fear. Answer as honestly as you feel about each statement. If you do so, you will be helping us very much.

At the end of each statement, there is space provided for you to answer in one of the following ways:

If you strongly agree with the statement, tick twice ✓✓

If you agree with the statement but not strongly tick once ✓

If you cannot decide, put a question mark ?

If you disagree with the statement, put a cross X

If you Strongly disagree, put two crosses X X

Example: Education is not useful to our country. XX

(This shows that I strongly disagree with this statement)

NOW START !!!

(APPENDIX III)

1. Mathematics appears hard even with increased effort .....

2. I choose to admire students who top my class in maths than try to top the class myself. .....

*3. Spending more time on my maths homework might bring me a better result. .....

4. I feel lazy when we are given maths homework. .....

*5. I like solving mathematics quizes even if they are not part of my school work. .....

6. Mathematics problems which appear difficult just frighten me off. ......

7. I do not like trying mathematics sums which I may get wrong. ......

8. I just hate mathematics competitions. ......

*9. Mathematics periods at school cheer me up. ......

*10. Even if my chances of success in solving maths problems appear small, I like trying my luck. ......

*11. I work hard on mathematics because I like it even if I do not score very high in it. ......

*12. My wish is more towards understanding maths than just passing tests. ......

*13. I enjoy doing mathematics homework. ......

14. After Grade Twelve, I should not like to study mathematics anymore. ......

*15. When I feel lazy to do some school work, I prefer to do some mathematics. ......

*16. When we have a maths test, I always hope to be among the best. ......

17. If I can, I always wish to avoid maths competitions. ......

*18. I work hard on maths to avoid failing. ......

*19. When I worry about failing my maths I do better ......

*20. Success in maths just brings me pleasant feelings and further determination to succeed . ...

*21. If maths tests appear hard, one must not give up. ......

*22. The teacher should give us time to try maths problems before showing us how to solve them. ......

23. When I get used to one method of doing maths problems, I get annoyed when made to change to a new method. ......

(APPENDIX IV)

*24. Good mathematicians have the best chances of success in life. ......

*25. To understand the present world well, one must know mathematics. ......

*26. I should be happy to study mathematics further after Grade Twelve. ......

27. We should stop teaching mathematics in our schools. ......

29. Mathematics is too difficult. ......

*30. I should be happy to read about mathematics in the future. ......

31. Most of what is taught in mathematics is not useful. ......

*32. Mathematics is the most interesting subject for me in school. ......

*33. Passing mathematics should be useful for my future. ......

34. The mathematics taught in school, does not add much more to the mathematics I need for my life. ......

*35. The mathematics knowledge and skills I learn in school should be helpful to me when I leave school. ......

*36. Almost anyone who is serious can learn mathematics. ......

*37. Any person of average intelligence can learn and understand a good deal of mathematics. ......

*38. Even difficult mathematics can be made simple to a secondary school student. ......

*39. Even complex mathematics can be made useful to every normal secondary school student. ......

*40. Most of the able people should be encouraged to become mathematicians, ...

*41. Mathematics is of great importance to a country's development. ......

*42. It is important to know mathematics in order to get a good job. ......

43. Unless one intends to become a mathematician or a scientist, the learning of advance mathematics is not necessary. ......

*44. In the near future, most jobs will require a knowledge of mathematics. ......

45. Most of the time, I just find that I can never see the importance of what we learn in maths. ......

NOW PLEASE CHECK IF YOU HAVE ANSWERED ALL THE STATEMENTS.

THANK YOU VERY MUCH !!!

(* marks items treated as positive or plus items referred to in Table 2 page 96 . Scoring was therefore as indicated in this Table).

APPENDIX V

STUDENT'S HOME SOCIO-ECONOMIC STATUS SCALE.

(maximum score points shown in brackets.)

Instrument : Main Study Socio-economic Status Scale.

ss No. ....

Dear Parent / Guardian,

The purpose of this questionnaire is to collect information to help find out more about factors which might be affecting students' achievement in mathematics. Knowledge of this kind might help towards finding ways of improving students' performance in mathematics. Towards this end, there is need to know more about the student's self, home and parents. But we do not require to know the names of the students nor those of their parents. This should free you to respond to ALL the statements below, freely and honestly with the assurance that the private information you give us will not be made public property under your name. The information you give us will be handled with utmost confidence so as never possibly to embarass you in any way what-so-ever. We earnestly request you therefore, to respond truly and honestly as you feel and know concerning the issues raised in the statements below. Your true and honest answers will be very valuable in helping us achieve our objective.

Part I is to be completed by the Father or Guardian who brought up this student now entering Grade Eight.

Part II is to be completed by the mother or corresponding guardian who brought up this student.

Part III. To be completed by the student.

Part I

To be completed by the Father or Guardian.

Write in the spaces provided or tick the option you choose.

1. What is your relation to this student ? ....

2. In your view, should girls be taught as much mathematics as boys ? (0

   very much so / perhaps yes / not sure / a little / not at all. (0)

3. Do you help your children at home when in difficulty with their mathematics homework ?

   Always / sometimes / Not sure / once in a while / Neve
   (5) (4) (3) (2) (1)

4. Thinking of yourself back in the 1970s when your child now in Grade 8 was still young, how often would you say you used to buy this child toys to play with ?

   Very often / often / not sure / once in a while / never
   (5) (4) (3) (2) (1)

5. If you used to buy any toys for this child, would you say these toys should have taught the child anything related to mathematics such as drawing or counting ?

   Yes very much / perhaps yes / not sure / a little /
   (5) (4) (3) (2)
   not at all. (1)

6. May we now ask you a few questions about yourself now and in the early 1970s when your child / ward now in Grade Eight was still very young.

   Consider and add together, the duration of your training in years in each of the educational (academic, vocational, technical and so on) qualifications you now have. Thenn for how many years from primary Grade One did you receive education ?

   .... years.

   (Points awarded according to scheme: 0 - 4 years (1); *5 - 9 (2) ; 10 - 13 (3) ; 14 - 17 (4) ; above £5*

7. *What is your occupation ?* ....

   (Professional (5) ; data processing, clerical (4) ; small business, technical skilled (3) ; labourer (2) ; none (1))

~~8. What position (rank) do you hold in this job ?~~

....

8. What rank (position) do you hold in this job ?

....
(Top (3) middle (2) bottom (1))

9. Consider the socio-economic stratification of our society in Zambia to day. If '5' represented the topmost most well off and '1' the bottom most worst off. Tick where you place yourself on the scale :

_____5____/____4____/____3____/____2____/____1____
richest poorest

10. What was your occupation in the early 1970s ?

....

Professional (5), clerical (4) technical skilled (3), labourer (2) , none (1).

11. What position (rank) did you hold in the job ?

....
Top (3) middle (2) bottom (1)

12. Consider again the socio-economic levels of stratification of our society in those early 1970s. If '5' represented the top most well off then and '1' the bottom worst off. Tick where you place yourself, in those days, on the scale :

_____5____/____4____/____3____/____2____/____1____

Thank you very much.

Part II

~~To be completed by the mother or mother guardian.~~
To be completed by the mother or mother guardian.

Write in the spaces provided or tick the option you choose.

1. Do you think girls should be taught as much mathematics as boys ?

Yes very much so / perhaps yes / not sure /
a little less / much less. (0)

2. Do you feel the mathematics taught, other than arithmeti
in school is useful for your child's future ?

very useful / useful / not sure / little use / useless.
(C

3. Would you say, you normally help your children with their mathematics homework when they are in difficulty

Always / sometimes / not sure / not usually / never.
(5) (4) (3) (2) (1)

4. Tick any of the following items which you could say your child, now in Grade Eight, had, at home before starting Grade One.

Children's water paints.
Drawing materials.
Geometrical shapes.
Counters.
Blocks.
Number toys.
Jig saw puzzle.

(5 for one or more ticked)

....

Pictorial books.
Pram rattles.
Word games.

(4 for one or more ticked)

....

Ball.
Doll.
Toy car.

(2 for one or more ticked)

Baby cot.
Baby pram
Playing p
Swing.
Tricycle.

(3 for on
or more
ticked)

....

(1 point
for non
ticked)

Give any not included in the list provided above

....

5. What is you relation to this student now in Grade 8 ?

....

6. *Consider and add together the normal duration in* training years for each of the educational (academic, vocational, technical and so on) qualifications you *have. How many years of education then, did you receive in all starting from Grade One ?*

(0-4, 1 point), (5-9, 2 points), (10-13, 3points), (14-17, 4 points() *(greater than 17 , 5 points).*

7. What is your occupation ? ....
(Professional / technical 5 points); (clerical/ administrative 4) ; (skilled worker 3) ;(Labourer 2) ; (none 1 point).

8. What is your position (rank) in your job ?
....
(Top 3 points); (middle 2) ; (bottom 1 point).

Could you please now check if you have responded to all the items .

Thank you very much .

....

Part III

To be completed by the student.

1. What is your date of birth ....sex ....
(0) (0)

2. What are the educational qualifications of your <u>most</u> successful elder sister (if any) ?
....
(none 1) ; (primary 2) ; (secondary 3) ; (tertiary 4).

3. What is her occupation ....
(professional/5.)(clerical/administrative 4) ; (skilled worker 3) ; (labourer 2) ; (labourer (none 1)

4. What position (rank) does she hold in her job. ?
....
(Top 3 points) ; middle 2) ; (bottom 1).

5. What is her husbands occupation (if married) ?
....
(Professional 5); (clerical 4);(skilled worker 3); (labourer 2) ; (none 1).

6. What are the educational qualifications of your <u>most</u> successful elder brother (if any) ? ....
....
(none 1); (primary 2); (junior secondary 3) ; (Secondary 4); (tertiary 5)

7. What is his occupation ?

....
(professional 5) ; (clerical 4) ; (skilled worker 3)
(unskilled worker 2) ; (none 1).

8. What position does he hold in his job ?

....
(Top 3) ; (middle 2) ; (bottom 1).

Thank you very much.
