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SUCCESS AND FAILURE IN MATHEMATICS AMONG STANDARD SEVEN STUDENTS IN THE BAFOKENG REGION OF BOPHUTHATSWANA

Joseph H. Kiely.

A Thesis submitted to the Faculty of Education, University of the Witwatersrand, Johannesburg in fulfilment of the requirements for the degree of Doctor of Philosophy.

Johannesburg 1990.

ABSTRACT

SUCCESS AND FAILURE IN MATHEMATICS AMONG THE STANDARD SEVEN STUDENTS IN THE BAFOKENG REGION OF BOPHUTHATSWANA. KIELY, Joseph H; Ph.D. University of the Witwatersrand, 1990.

This research investigates success and failure in mathematics at the standard seven level in middle schools in the Bafokeng region. There is great concern expressed by parents, teachers and students about the high failure rate in this subject in the external examinations. Mathematics is seen to be important for securing good jobs in the platinum mines which are situated on the Bafokeng tribal lands. In general, greater efforts by teachers and students have made little impact on the public examination results.

The present study undertakes an in-depth analysis of this problem in the anthropological paradigm using the illuminative approach. Interviews and questionnaires are used for gathering data and triangulation techniques are used for verification and checking. Statistical correlation is applied to the variables but the study is not limited to numerical relationships between factors associated with scholastic success and failure. Two separate criteria of "success" are defined, namely the standard 7 mathematics mark and the performance of a ten per cent sample in each of five picture problems. The

population is composed of one educational unit: the one high school in Phokeng, capital of the Bafokeng, and the three middle schools which make up the catchment area of this high school. The number of students involved is approximately three thousand.

Language and attitudes show strong positive correlations with both criteria of success. Other variables, like socio-economic status and degree of westernization are significantly related to the picture problem scores but not to the mathematics mark. Surprisingly, self-concept and embedded figures scores show no statistically significant relationship with either of the two criteria of success.

In order to succeed in school mathematics a student must attain a high level of abstraction. This research does not suggest that the case is any different for Bafokeng students, but it attempts to explore the modes of perception, methods of concept formation and the development of appropriate schemata by which abstraction is achieved. Finally the implications for teaching and learning of mathematics in school are discussed in the light of the findings of this research.

This is the first study of its type, as far as can be ascertained, for Bophuthatswana schools.

DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the degree of Doctor of Philosophy in the University of Witwatersrand Johannesburg. It has not been submitted before for any degree or examination in other University.

Joseph H. Kiely

30th day of March, 1990

DEDICATION

I wish to thank Professor D. White, my promoter and supervisor, for his encouragement and guidance which made this research a deep educational experience for me. I also thank his wife, Eileen, for advice as well as the hospitality of her house on numerous occasions.

I thank Arthur Chciowicz, Anna Ferreira and Margaret Sutherland for help in the statistical analysis; Beth and Lona Perrins for the typing; Anne Finnegan for technical assistance; Anton Fobian for printing.

I thank the principals, teachers and students of the schools of the Bafokeng region who taught me much more than I taught them.

I thank my religious family: James, Farr, John, Hilary and Eileen for tolerance and support.

In a very special way I thank Georgina without whose assistance this work would not have been possible.

To all of them I dedicate this thesis.

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CHAPTER 1

Background to the Research

1.1. Introduction

The topic being researched in the present study concerns an aspect of education among the Bafokeng of Bophuthatswana among whom there has been an expressed need for schooling since the middle of the last century. As long ago as the eighteen sixties the then chief Mokgatle realised the importance of being able to read and write and he visited Lesotho to see at first hand young children learning these skills in special mission schools (Coertze 1987 P.43). The Bafokeng tribal lands contain some of the richest mineral deposits in the world including sections of the platinum bearing Merinsky reef (Walraven 1981 P.29). Extensive mining development over the past quarter of a century has helped to transform the Bafokeng from a rural-agricultural people into a group who are conscious of the powerful forces for social change exerted by western technology.

The present study is situated in a period of change: the old ways are being challenged, the values and customs of the elders are being replaced by an imported culture propagated by newspapers, radio and television. People who could once walk leisurely through their own

village to visit their friends are now forced to stand on the side of the road and wait while streams of cars rush by on their way to Sun City, a mere 30 kilometres to the north west of Phokeng. Old men who spent their own youth running after goats or herding cattle must now find money to pay school fees and buy school uniforms for their grandchildren. Schools are now seen to be the gateway to a new material prosperity. The Bafokeng tribal authority has invested large amounts of money in providing school buildings and facilities for its children (Moletlegi 1985 P.12). However just as elsewhere in developing countries (Thompson 1981 P.86-93) such investment has not yielded the hoped-for high returns. The obvious question being asked is Why? Why are so many children not able to get good jobs after completing many years of schooling? Why are so many students failing the school examinations? What is wrong with the schools and the teachers? Why are Bafokeng workers employed mostly as labourers or in low paid clerical jobs in their own mines? What is required of someone to become a shift boss underground? How can a person become an engineer or a manager? One answer often heard in Phokeng and which is at least partly true goes like this: "One needs a good matric and this means good symbols in maths and science as opposed to passes in Afrikaans and Bible studies". This inevitably leads to the further question: Why are so few Bafokeng stu-

dents doing maths and science in the high schools and moreover why do so many of those who take maths fail so miserably?

In the 1988 matric examination an estimated 17 000 Bophuthatswana students wrote the examination. Approx 3000 of these did maths and only 800 passed, which is a mere 5% of those who entered for the examination. It is to address such questions that the present research has been undertaken. It set out to investigate the factors associated with success and failure in mathematics among the Bafokeng.

This research started by looking briefly at the history of the Bafokeng and tried to single out what characterises them as a group of people. It was necessary to study the problems they have faced in the past and how they have coped with changes forced on them by close contact with other cultures such as the Matabele, the Voortrekkers, the Boers, the English speaking whites etc. The history of schooling in Phokeng is outlined and the problem areas which emerged down the years and how they were dealt with is given. Lastly this chapter has a broad description of how the investigation was carried out.

1.2. The Bafokeng

1.2.1. Origins and early history of the Bafokeng

The Bafokeng* make up just one tribal unit among the Batswana* who inhabit the Republic of Botswana* and the South African independent homeland of Bophuthatswana. Both countries are named as places occupied by the Batswana*. Apart from an artificial boundary the people in these countries are the same, claiming a common origin, speaking the same language called Setswana*, and having the same customs, traditions etc. (Mangope 1988 P.28). The geographical location is shown in Fig. 1.1. and Fig. 1.2.

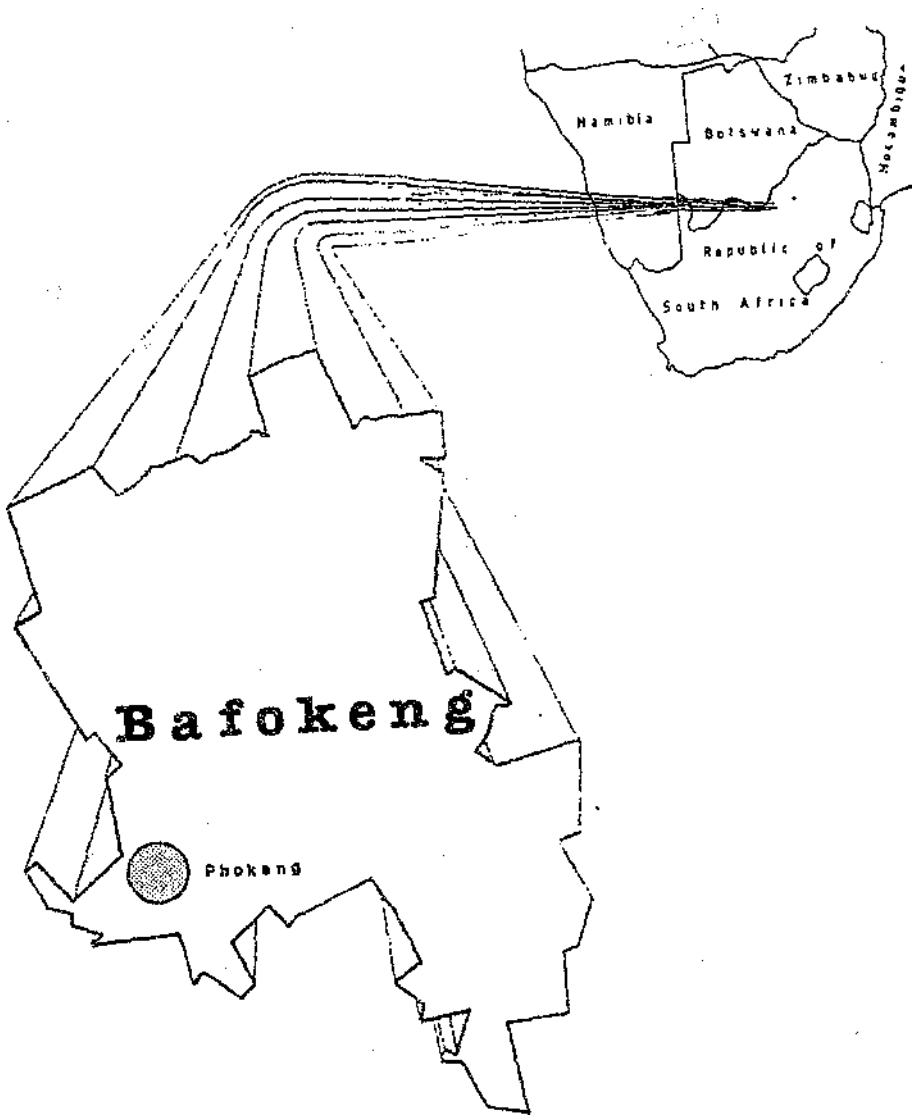
Researchers have been unable to ascertain with any degree of certainty where the Tswana-speaking groups originated. Based on linguistic and cultural evidence there is no doubt the Tswana and Sotho groups are linked (Ruperti 1975 P.14). Schapera (1953 P.15) claims the Tswana-Sotho tribes migrated from East Africa and entered South Africa probably through the western portions of southern Rhodesia in three series of migrations.

* In the language spoken by the Tswana people prefixes are used with a common stem in the following manner:

---

ba = the people of; thus baTswana = the Tswana people, baFokeng the Fokeng people. It is customary to write Batswana and Bafokeng in English.
bo = the place of; thus boTswana = the place or country of the Tswana. It is customary to write Botswana.
se = the language of; thus seTswana = the language of the Tswana. It is customary to write Setswana.

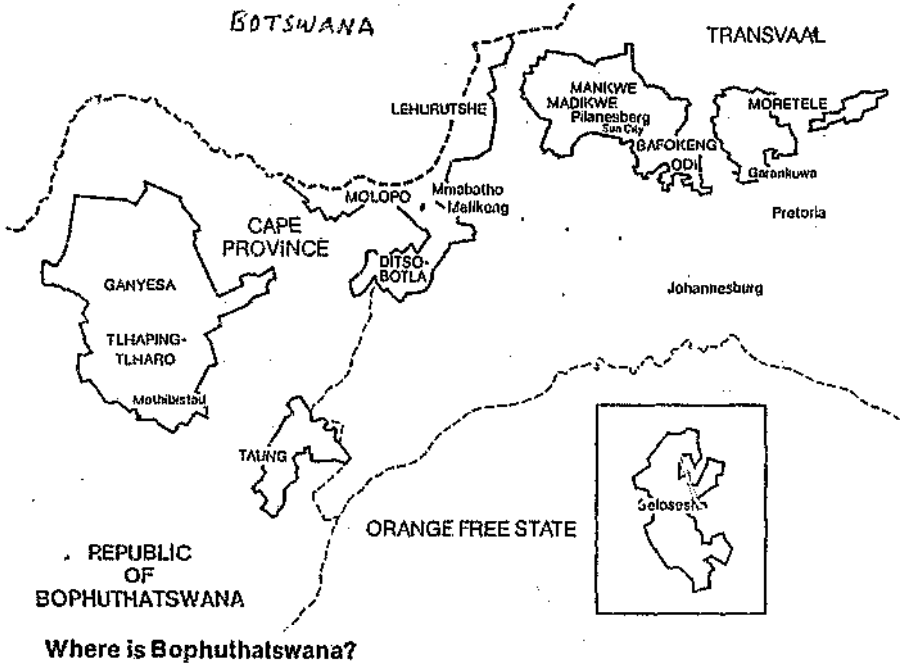
Fig. 1.1. Geographical location of the Bafokeng



The third and greatest migration brought the ancestors of the Tswana-Sotho groups who settled as a body in the south western portions of the modern Transvaal and then broke up rapidly into separate clusters. The people in one of these clusters identified themselves with the Kwena (crocodile) totem and this group later still sub-divided into several tribes, one of which was the Bafokeng (ibid). Breutz (1953 P.56) agrees with the broad outline, but there is considerable disagreement about the dating of the events. Breutz (1953) bases his estimates on oral tradition among the Bafokeng and suggests the Bafokeng entered the Transvaal in the 18th century. Coertze (1987) also worked on oral tradition and came up with a similar conclusion but dated it well before 1700 (ibid P.25). Ruperti (1975) quotes still other sources and states categorically: "Blacks spread to the rest of South Africa after the arrival of the Whites" (ibid P.13). Archaeological evidence studied by Mason over a period of thirty-five years indicates a different origin dating back to as early as 350 A.D. Mason has examined 47 sites in the southern and western Transvaal and has dated them from 350 A.D. to 1820 A.D. He claims these sites indicate the origin of the Sotho-Tswana people (Mason 1983 P.261). Other scholars such as Evers agree that the Iron age material dating from 1200 A.D. is indeed ancestral Sotho-Tswana but don't agree that the fourth century remains can be identified

with the present day Tswana groups (Evers 1983 P.262). Evers rejects the 4th century origin and claims the Sotho-Tswana arrived in South Africa about 1200 A.D. as an intrusive group overlying an earlier Iron age tradition (ibid).

Fig 1.2. Republic of Bophuthatswana



Where is Bophuthatswana?

Bophuthatswana comprises seven regions situated within the geographical area of South Africa. These regions were part of the original lands of the Batswana before the British Government annexed them into South Africa in the years preceding and following the Boer War. The other part of the lands of the Batswana were constituted by the British Government into the Bechuanaland Protectorate which was given its independence by Great Britain in 1966 as the Republic of Botswana.

The above discussion might seem irrelevant for the present research were it not for the political and economic importance attached to it by today's leaders. The South African Government claims equal rights to the land in the Transvaal basing their claims on the supposedly simultaneous arrival of whites from the south and blacks from the north (Ruperti 1975 P.13).

Black leaders such as Dr. Lucas Mangope, President of Bophuthatswana, reject such claims:

> Contrary to the propaganda of the South African Government that the we came to this part of Southern Africa together, that they were travelling up from the south and we were travelling down from the north; it is known that by the year 450 A.D. the Tswanas were already settled where they are today and where they have been displaced (Mangope 1988 P.23).

Edward Molotlegi, chief of the Bafokeng also supports the earlier date and he claims his tribe "have lived in what is known today as the Rustenburg area, from time immemorial" (Molotlegi 1982 P.2). It must be remembered that the disputed land contains rich mineral deposits including some of the most easily accessible platinum bearing rocks in the world. Claims to ownership have led to friction not only between white and black but also between the Bafokeng and the Bophuthatswana Government (Semane Molotlegi 1989 P.35). There seem to be two aspects to this dispute. First, and most obvious is the disagreement as to how the profits from the Impala platinum mines should be shared. In one year royalties paid to the Bafokeng Tribal Authority amounted to R16,5

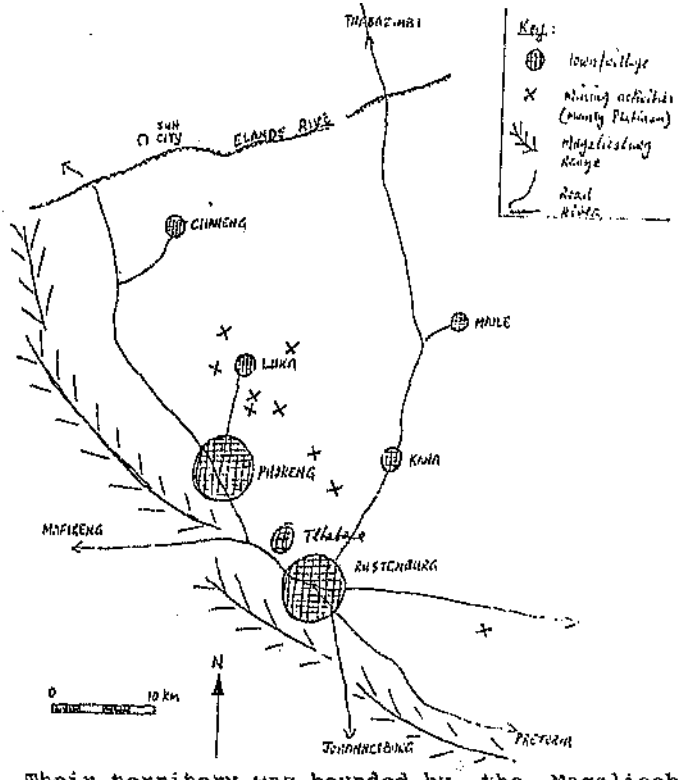
million while taxation on mining revenues reaped Bophuthatswana Government R92,5 million (Molotlegi 1985 P.11). The Bafokeng tribe believe they are entitled to a bigger share of the profits since they are the legal owners of the land. Second there is disagreement concerning matters of government. The Bafokeng chief is the 10th in a long line of succession unbroken back to the 17th century (Coertze 1987 P.18). He is the traditional head of the tribe and rules with the assistance of a group of elders called the Kgotla. In 1977 Bophuthatswana was declared independent and the Bafokeng lands were incorporated into the new state headed by President Lucas Mangope. Mangope has dedicated himself to establishing a Tswana nation along modern democratic lines with a constitution, parliament, civil service, judiciary, police, army etc. such as exist in most western countries in the eighties. This has led, inevitably, to conflict with the traditional rulers - the chiefs - who don't wish to abandon the ways of their fathers. It can be seen that even at the highest political level conflicts exist between tradition and modernization and the strains of coming to terms with change have exerted terrible pressures on the people involved.

Returning again to the wider South African scene one direct outcome of the conflicts there is the black-white polarization and the doctrine of apartheid which has

dominated the political and social lives of the people down to the present day. The school system too has been affected by apartheid and black children have been subjected to "Bantu education" for more than thirty years (Christie 1985, P.226). This topic will be taken up again in section 1.3. below.

There is general agreement that the Bafokeng tribe was well established by 1800 A.D.

Fig 1.3. Phokeng - Rustenburg district



Their territory was bounded by the Magaliesberg moun-

tains to the south and the Elands river to the north as shown in Fig. 1.3.

The tribal identity was established with its line of chiefs, its totem, its kgoro* and villages (Schapera 1953 P.46). They had engaged in wars and cattle raids, and stories from that time speak of a general contentment and prosperity (Coertze 1987 P.25-34).

This period of peace was shattered in the early part of the 19th century by famine and invasion. The worst destruction and misery was caused by the Matabele regiments who under their leader Mzilikazi are reported to have wrought devastation and destruction wherever they passed (Bulpin 1965 P.31-45). These years were difficult ones for all the Tswana tribes of the western Transvaal and some suffered extinction at this time. Not so however for the Bafokeng, who managed to tread a wary path between the various parties and even managed to keep some form of diplomatic relations open with Mzilikazi since they had representatives at the feasting organised to celebrate the Matabele defeat of the Barolong (Plaatje 1930 P.53). Later even after Mzilikazi fled northwards after his defeat at the hands of Potgieter allied with the Bafokeng among others (Plaatje 1930 P.142), some special links were maintained between the Bafokeng and the Matabele.

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*Kgoro - The Tswana people lived in large villages divided into sections called Kgoro or "ward".

In 1870 when civil war broke out among the sons of Mzilikazi, now settled in the southern portion of Rhodesia, a contingent of Matabele fled southwards into the Transvaal and found refuge in Phokeng (Coertze 1987 P.37). Nkulumane, a son of Mzilikazi, turned up in Phokeng about this time and married into the tribe. He died in 1883 and his grave is marked as an important historical monument in Phokeng to this day (ibid).

From the brief account given here it can be seen that during the 19th century the Bafokeng developed a strong image of themselves as a unique group. The foundations were firmly laid for the emergence of a people whose uniqueness is well described in the following words:

> ... my people consider themselves first baFokeng-baKwena, then Tswana, then African and, only then, Black (Molotlegi 1985 P.1).

1.2.2. Contact with western culture

Early in the eighteen hundreds first contacts were made with white hunters and traders. Missionaries such as Moffat of the London Mission Society passed through the Bafokeng area in 1829 (Coertze 1987 P.35). It was only in 1844 that formal contact was made between Chief Mokgatle of the Bafokeng and Hendrick Potgieter one of the Voortrekker leaders (ibid P.39). The meeting was cordial and both leaders showed mutual respect and this remained a feature of relations between the Bafokeng and the Boers who later settled in the area under the

leadership of Paul Kruger (Molotlegi 1985 P.9). Bafokeng warriors joined the expedition led by Potgieter against the Matabele, inflicting heavy losses on them at Mosega in 1837 (Plaatje 1930 P.142). They also assisted the Boers in their fight against the British in the Anglo-Boer wars (Coertze 1987 P.40).

About 1866 Chief Mokgatle moved his principal village from Kana, a site north of Rustenburg, to Phokeng but there is evidence that there had been a flourishing settlement at Phokeng long before this (ibid P.39). At the same time the Hermannsburg Missionary Society was invited to set up a mission station in the new capital and they established themselves at Saron close to Mokgatle's own home. They laid out rectangular streets and plots for their own converts and that part of Phokeng is still today in stark contrast to the rest of the village where the lines are not straight and the development seems haphazard by comparison. From 1870 to 1900 there was a gradual takeover of Bafokeng land and the setting up of white farms. As early as 1855 several Bafokeng wards had been handed over to the whites for their occupation (Molotlegi 1982 P.3). Relations were friendly in spite of this and Chief Mokgatle and Paul Kruger were personal friends. A meeting between the white settlers and the Bafokeng was chaired by Kruger in Phokeng in 1883 and a large farm was carved out of the western section of the tribal land and became Kruger's

own farm which he named Boekenhoutfontein (ibid).

Chief Mokgatle soon realised the dangerous predicament facing his people and that if the trends continued they would soon be without any territory of their own. On the advice of his white friends he decided title deeds must be secured for their traditional lands. At that time blacks were not entitled under the law to own land and the sales were organised through a third party - usually the Reverend Penzhorn of the Lutheran mission at Saron. Money was needed for this project and regiments of 50 to 100 men were sent to Kimberley to work as labourers in the diamond mines. On their return they were levied £10 per head payable into the tribal treasury (Coertze 1967 P.40). Not all of them returned, some died on the way and others were killed as a result of accidents at the diggings or from disease. A monument to these young men at Kimberley carries the inscription:

> Rest well men of the dew (baFokeng). In death there is life. In bondage freedom. The Council fire burns brightly on Direpotsane and our grandchildren will honour you (Molotlegi 1985 P.9).

The success of this scheme can be judged from the purchase of Beerfontein farm which includes Phokeng, from Paul Kruger at a price of £900. The cost was shared by the Lutheran mission (£220), and the Bafokeng paid out £680 (ibid P.43). From this incident can be seen how adaptable were the

Bafokeng authorities. They readily saw the changes that were taking place and quickly learned how to earn and use money. They also learned the intricacies of the white judicial system and were soon using it for their own purposes (ibid). The Hermannsburg Missionary Society was undoubtedly the most influential in bringing about cultural changes among the Bafokeng. The missionaries at Saron opposed polygamy, initiation schools, sorcery, rain ceremonies and ancestor worship for example. They also helped to introduce the idea of town planning, the erection of rectangular buildings and they helped the Bafokeng to understand the new money economy. For the purposes of the present research, however their most important contribution was undoubtedly the introduction of western style education, which is dealt with in section 1.3. below.

1.2.3. Traditions and customs

There are two possible approaches to the study of the traditions and the customs of the Bafokeng. One possible approach is to view them as one among many tribes making up the Tswana people estimated to number up to 3,5 million people (Mangope 1988 P.14).

There is an analysis of the Tswana national character available in the literature carried out by Kiely (1983 P.127-133). This analysis was based on a method used by McClelland (1975) in his study of the Indian national

character (P.126-130). Briefly the steps are:

a) listing facts about the group being studied which would be representative of their observed behaviour;

b) designing classes which must include all the basic categories of cultural life and assigning t' facts to these classes;

c) scrutinising proverbs and folktales in order to arrive at the group's own interpretation of these facts;

d) discussing with local people how they viewed the facts;

e) trying to discover the fewest possible themes or propositions that seem to account for the facts (ibid P.127).

The application of this method is further developed in chapter 7 of the present research where the list of facts and the categories are given. The dominant theme that emerged from the application of this research method to the Tswana people was the interdependence of people. This interdependence is important for the whole group of Tswana speaking people considered as one nation but is much more important at a local level between members of the same tribe. For the Bafokeng, mutual dependence has given rise to insistence on good human relations which, is presented as the most outstanding tribal characteristic (Kiely 1983 P.132).

A second approach is to undertake an historical analysis

of the Bafokeng tribal history and try to identify what characterises them as a group. Much of the historical material has been outlined in the previous section and it will not be repeated here.

In reading the history of the tribe since 1800 one is struck by their adaptability to rapidly changing conditions; they survived the destruction and famine and wars of the Matabele reign; they survived the more subtle invasion of the white men. They were very fortunate that during this period they had as chief the very wise Mokgatle (1834-1891) to guide them through those years. He it was who led his people through the altered life style imposed by the new economic order and the new judicial system brought by the whites. Mokgatle too realised that future success for his people lay in schools and he set about introducing western education for his people (Molotlegi 1985 P.9). It was Chief Mokgatle who was responsible for bringing christianity to the area when he invited the Lutheran missionaries to Phokeng. He gave them every support even when they opposed traditions and customs going back for generations. He himself became a Christian late in life and he was buried from the Lutheran church in the Christian cemetry. Traditionally, land belonged to the chief as head of the tribe. The chief granted stands for houses and agriculture to his people as needed. Grazing was common for everybody although numbers were controlled.

The Boers introduced a totally new system of land tenure based on a money economy and involving title deeds. The Bafokeng found themselves dispossessed overnight. However once they became aware of what was happening they set about procuring these new papers of ownership but they found a new obstacle in the money payment that was needed. Nothing daunted, the Kgotla organised young men to work in Kimberley and bring back money, as was described in section 1.2.2. above. By the time of Chief Mokgatle's death in 1891 five farms had been purchased in this manner.

The legal system practised by the whites was another innovation. Again the Bafokeng learned quickly how to use this system to their own advantage and soon they were making use of it to protect themselves. One early example quoted by the tribal story tellers concerns a certain white farmer named Frans Smit who was supposed to have struck Chief Mokgatle with a sjambok. The chief brought a case against Smit in the courts. Smit was found guilty and fined (Coertze 1987 P.40).

In more recent times the same adaptability has characterised the Bafokeng. Platinum and the mysteries of chemical and electroytic extraction of minerals burst on them in the sixties. Not only did they cope with the changes which flooded in with the new technology but they were able to turn these to their advantage. When the Impala mining company applied for prospecting per-

mission to the Bafokeng Kgotla they were surprised at the astuteness of these tribesmen. The Kgotla reminded the Company that they were granted the permission to prospect but they had no right to start mining operations. When they finished the survey they must come again and report to the people what they were planning to do. Eventually a contract was made whereby the Impala company would pay 13% royalties to the tribe and R20 per morgen for surface development (Appendix A No. 3).

And in the eighties the Bafokeng tribe continues to adapt to changes such as industrialisation, migrant labour, modern banking,shopping complexes and so on. Coertze gives the following interpretation of the scene:

> The general effect of these westernizing influences has been so pronounced that one sometimes doubts whether the traditional culture has the capacity to absorb these extraneous elements without being a together overwhelmed and swept away by the sheer assertiveness of the example which is presented as desirable. However our own observation of the factual situation indicated that although westernization is certainly taking place, the traditional heritage re-asserts itself in the most unexpected situations. This suggests that the process is unlikely to result in cultural replacement; it seems more probable that a convergence or synthesis is in the process of developing (Coertze 1987 P.66).

It is in the context of adapting to new situations that the need for mathematics is being felt. The needs are being expressed most keenly in the area of personal and family finance, shopping, budgeting, insurance etc. And related to this is the matter of better jobs, meaning

higher wages and easier conditions with less physical hardship. Among the more educated people there is a clear realisation that mathematics is essential not only for surveying, engineering and ultimately management positions in the mines but also maths is a route to technikons, medical school, business and many more professions (Appendix A No. 4).

This section dealing with the origins and history, traditions and customs of the Bafokeng is based largely on research done by other workers. A brief summary of this research is given in the next section.

1.2.4. Previous research among the Bafokeng

The Bafokeng tribe has attracted considerable interest among workers in various fields of knowledge. One of the reasons for this must be the survival of the tribe as an entity with many traditions and customs intact through 200 years of turbulent change right up to the present time.

Moffat and Livingstone wrote about their travels through the Bafokeng lands in the 1820's. They described the devastation and famine which were rampant. Moffat is remembered in the area from having his name associated with a very big tree ppinted out as "Moffat's tree" near Phokeng. He is reported to have counted many people living in that tree, presumably to escape cannibals and animal predators (Appendix A No. 2).

The work of the Lutheran missionaries in Phokeng has been the subject of many pamphlets written in German. Some of these are in the possession of Martin Penzhorn, living outside Rustenburg. He is a direct descendent of the first Lutheran pastor to arrive in Phokeng. A more comprehensive account is contained in the three volumes published in Germany by Hacius (1907-1920) and used by Coertze (1987).

Schapera (1953) produced an ethnographic survey of the Tswana under the auspices of the International Africa Institute, London.

Breutz (1953) surveyed the tribes of the Rustenburg district for the department of Native Affairs, Pretoria. His book contains a great amount of statistical material such as lists of schools and enrolment at the time of the survey. He devotes forty pages to the Bafokeng and gives an account of the tribal history as he recorded it from a group of old men called together for the purpose by the chief.

Coertze submitted his doctoral thesis in 1966 at the University of Pretoria and an English translation was published in 1987 with the title Bafokeng Family Law and the Law of Succession. Most of this work is taken up with court cases dealt with by the tribal Kgotla. While these cases give a very good insight into the working of the law they also enshrine values traditions and customs of the tribe. Chapter 2 has a detailed history of

the Bafokeng which uses all the known published sources as well as drawing on the memory of the elders of the tribe. Coertze makes only passing references to schools.

For over thirty years R. Mason (1983) has been studying the archaeology of the western Transvaal and has numerous publications and journal articles in which he presents his findings and his theories. As far as can be ascertained no site on Bafokeng land has been excavated. Novels such as Sol Plaatje's Mhudi (1930) and Peter Becker's Path of Blood (1962) give a vivid picture of life and times during the reign of Mzilikazi who sojourned in and around the Bafokeng area during the first half of the 19th century. R. Bulpin (1965) also refers to the same period but from the viewpoint of the voortekkers in his book Lost Trails of the Transvaal. The views of the present chief of the Bafokeng are set forth in a 1982 handout written by him personally, entitled A short note of the history of the Bafokeng. Another pamphlet which develops these notes of the chief came to the notice of this researcher in 1985 it is entitled simply The Bafokeng.

Kiely (1983) reports material gathered in interviews with several old men of the tribe in chapter 2 of an unpublished research report at the University of the Witwatersrand. This work also contains numerous first hand observations as well as a discussion of the value

system among the Bafokeng. Several other interviews have been recorded during the present investigation and the remarkably vivid accounts given by the old men are a joy to hear at first hand.

In so far as can be established education among the Bafokeng has been a neglected topic and no previous research in this field has been uncovered. There is a wealth of source material available and it is hoped that such a project will soon be undertaken.

The present research cannot do justice to the history of schooling among the Bafokeng nor was this the intention. Nonetheless for a proper understanding of the background to this research into mathematics a brief survey of the manner in which western type schools developed in the Bafokeng region is neccessary and this is given in the next section below.

1.3. Education among the Bafokeng

1.3.1 History of the schools

Traditionally tribal history, customs and values were transmitted to the young men and women at the initiation schools (Bophuthatswana Education Report 1978, P.5). Each graduation group was organised into a regiment and membership of this regiment lasted all through life. The initiation school for the Bafokeng was situated at Kwaling near Maile. The last regimental name to be used was "Matsie" (locusts) but all the men of that regiment

are long since dead (Appendix A No. 3). It seems the strong opposition of the Lutheran missionaries succeeded in doing away with the initiation schools (Coertze 1987 P44).

In deference to the missionaries Chief Mokgatle had decreed in 1875 that no Christian was to be forced to attend the initiation school (ibid).

As mentioned earlier it was Chief Mokgatle who first realised the importance of western type schools for the advancement of his people and having heard of such schools operating in Lesotho he visited Moshoeshoe's kingdom to learn more about them. On his return from this visit Chief Mokgatle contacted the Hermannsburg Missionary Society immediately and the Rev. C. Penzhorn was sent post haste in 1866 to open a mission station in Phokeng (ibid p.43). As well as building a church the Rev. Pentzhorn started literacy classes for the purpose of catechetical instruction and Bible reading. These church schools were very popular and spread to other centres such as Kana and Luka (Appendix A No. 3). Thus the great work of bringing literacy to a whole generation of Bafokeng was begun. The language used was Setswana and scholars paid a shilling a month for school fees. The aim of these schools was to prepare children for confirmation but they were also taught to read and write and even do simple arithmetic. The nature of the confirmation schools remained unchanged until well into

the present century as this extract from one interview recounts:

> I was born on the 22nd October 1900. I grew up herding sheep and goats first and later I herded cattle for my father. I attended school from 1915 to 1917 and that school was in the old village. It was a church school, an old Lutheran school. We had only Batswana teachers and my first teacher was Maria. My father paid the school fees for my brother Benjamin and myself but he couldn't allow us both to attend school at the same time. He needed one to look after the cattle. I did one week school and one week to look after the cattle. When I was in school my brother was with the cattle. In 1918 I made my confirmation and then I had to leave school (Appendix A No. 3).

The desire for schooling was very strong because the Bafokeng saw it as a gateway into the prosperity of the whites. They had seen what could be done by the new technology at Kimberley diamond mines and later in the Johannesburg gold mines; they had experienced at first hand the mighty havoc wrought by the guns of the Voortrekkers and soon rumours of mighty steam locomotives pulling wagon after wagon in a long line on railway tracks began to spread. The so called "mineral revolution" was well under way in the Transvaal (Denoon and Nyeko 1984 p.101) before the turn of the century. The Lutheran confirmation schools were very closely tied to the Bible and the early missionaries in Phokeng, just as elsewhere in Africa, failed to understand the culture and traditions of the people.

> The result was that only the formal mechanics of Wester education were accepted while the inner core or soul of the system, such as character development, socialization and other intangibles which create the ethos of Western culture, simply could not be

> transplanted wholesale into a totally different society which possessed its own cherished culture (Bophuthatswana National Education Report 1978 P.6).

The Bafokeng were not satisfied with the limited range of subjects offered by the Lutheran schools. The move for a wider curriculum which would include arithmetic, geography and music, was spearheaded by Dedrick Pitsoe (Kiely 1983 P.18). Pitsoe had worked in the Kimberley mines before training as a teacher at Lovedale. His efforts to introduce new subjects brought him into conflict with the Rev E. Penzhorn, manager of the Lutheran school in Phokeng. Supported by the Chief Molotlegi Mokgatle Pitsoe left his post at the church school and established a private fee paying school in his own house in Kgale section of the village (Appendix A No. 4). This school set a premium on English and arithmetic. There was also music on the programme and Dedrick Pitsoe even started a brass band which travelled as far as Johannesburg to give recitals (ibid). Malachy Mputle describes how he himself came to realise the importance of arithmetic for his own livelihood:

> I went to work in Johannesburg in a butcher's shop. That was in 1920. You see they wanted people who could read for delivering the meat so you could know where to bring it I was with some friends at Turfontein racecourse one Sunday and we saw someone selling bananas and oranges outside the gates. We started a discussion about how to make money by selling a pocket of oranges. I couldn't do it because I wasn't good at addition. My friend who had gone to school in Lesotho told me:
> "You can't make a business if you can't calculate".
> I asked him: "What can I do?" He told me: "You must go to school man". I asked him: "Will I be able to count and add if I go to school?" He told me

> about a night school in Booysens on the other side of Johannesburg. That was a Sunday. On Monday I went out and bought a lamp for my bicycle and I went to that school at 7.30 pm. I found a Xhosa mistress there and I told her I had finished standard one at home and I wanted to do standard two. They tested me and put me back to standard one again (Appendix A No. 3)

Malachy continued his schooling until he completed the Junior certificate in 1928. The lessons in counting and calculation have stood him in good stead throughout his life and even today aged 89 years he runs a project (in his own backyard) which consists of 600 laying hens and he sells 20 to 25 dozen eggs a day. Whether it was Dedrick Pitsoe's break with the church schools or a more enlightened management, the Church authorities established more orthodox primary schools which operated side by side with the confirmation schools for many years. Gradually the confirmation schools became phased out of the school day and became weekend and afternoon classes, but still taken very seriously. To this day several teachers in Phokeng give their time on a voluntary basis to help prepare candidates for confirmation in the Lutheran church. Just a few years ago in 1984 the three eldest sons of the present chief together with a large group of other boys and girls were confirmed. The rejoicing, dancing and feasting made the occasion such that one was reminded of what the graduation from the initiation school must have been like in the old days. Pressures for change also came from the setting up of

other Christian churches in Phokeng. One of these - the Pentecostal Holiness Church was established by the Rev Spooner (Breutz 1953 P.72), an American negro who came to the village in the nineteen twenties. As well as conducting services he built a school to serve the needs of his own converts and there was considerable rivalry between himself and the Rev E. Penzhorn (Appendix A No. 2).

Schooling in Phokeng over the first half of this century followed more or less the same pattern as the development of the so-called "mission schools" in the Union of South Africa. The growth was uneven and educated blacks posed a threat to the segregation policy of the newly elected Nationalist Government which came into power in 1948 (Denoon and Nyeko 1984 P.197). In an effort to rationalise the situation the Eiselen Commission was set up in 1949 and the Eiselen Report was duly submitted two years later (Rose and Tunmer 1975 P.244). The report was highly critical of all the church bodies involved in education:

> School control by religious bodies has created a multiplicity of administrative units of very unequal size and efficiency and with widely different conceptions as to the aims and practices of education (ibid P.247).

Elsewhere the report noted the conflict that contemporary African education produced between traditional tribal society and western European society which usually led to pupils despising tribal culture in favour

of western culture (ibid P.248). This section of the report is sharply contradicted by the information provided by the old men interviewed during the course of the present research. No evidence was found in their stories that they had come to despise traditional tribal culture as a result of their attending mission schools run by the Lutheran church. However the Bophuthatswana Report 1978 quoted earlier seems to support the Eiselen Report in this matter. This raises questions about the validity of published reports of this nature which sometimes rely on hearsay material. There is great need for grass roots research of the kind undertaken in the present study to clarify such issues. Any deeper investigation of the criticisms leveled at the mission schools by the Eiselen Commission is outside the scope of the present research. An interesting debate on the topic is given in Christie (1985, P.219 - 231). What is of interest here is what happened after the acceptance of the Eiselen Report. Legislation was prepared and two years later the Government passed Act No.47 of 1953; later on this act came to be known as the infamous "Bantu Education Act" (Rose and Tunmer 1975, P.258). In passing, it must be recorded that this act created the Bantu education system which was so violently rejected by South African black school children during the Soweto riots of June 1976 (Denoon and Nyeko 1984 P.217). In Phokeng the Bantu education department took over the su-

pervision of the Bafokeng tribal and church schools. At that time there were fourteen primary schools in the Bafokeng region (Breutz 1953 P.73).

In the forties a certain Mrs McGregor, as the local Transvaal education organiser for the Phokeng area, was instrumental in setting up a secondary school in the old house belonging to Chief Manotshe (Appendix A No. 5). A few years later funds were raised by the tribal Kgotla and a brand new building was erected in 1945 and named Bafokeng High School (Coertze 1987 P.57). The curriculum included several handicrafts (Breutz 1953 P73). The course spread over five years from standard 6 (Form I) to standard 10 (Form V) and students took the Junior Certificate examination after a minimum of three years i.e. at standard 8 (Form III).

The Senior Certificate examination could be written in standard 10 (Form V). Entry requirements for teacher training which had been Standard 6 Certificate were now raised and teachers were recruited from Standard 8 with the result that large numbers stopped attending at that level and only few continued to standard 10 and the Senior Certificate. The number rarely exceeded 20 students entering matric in one year. It was only in 1983 that the teacher training colleges in Bophuthatswana stopped enrolling students with Standard 8 Certificates. In 1962 the old premises were deemed by the Kgotla to be insufficient for increased enrolment and a new site was

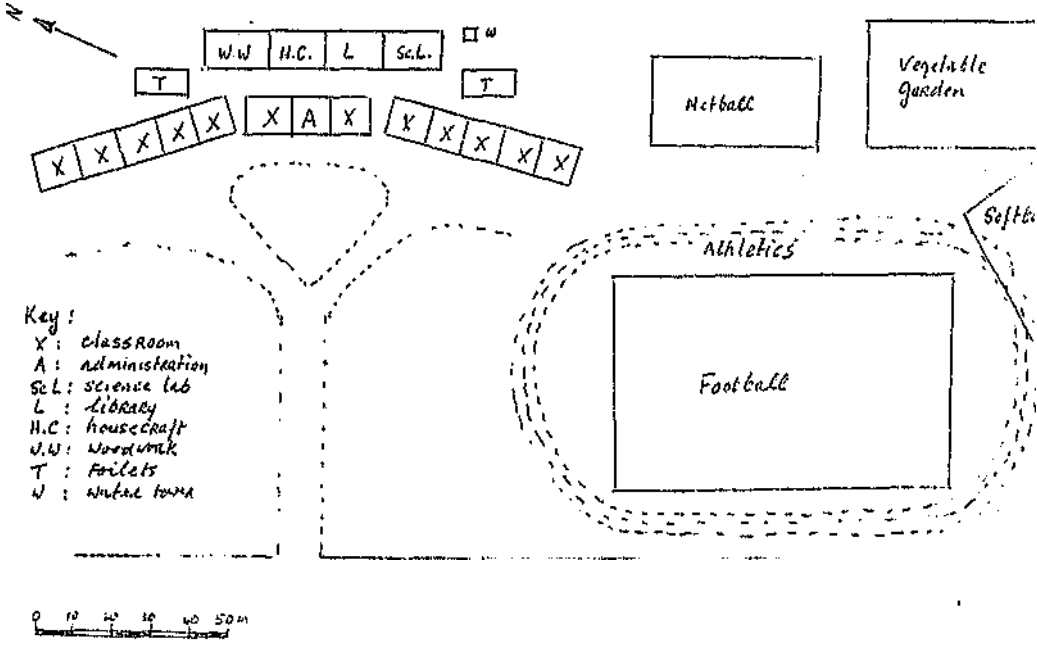
chosen two km away to the East. A new campus was established and a building consisting of two blocks of classrooms, an administrative block and a fourth block containing special subject rooms was erected. This campus continues to serve Phokeng as the present Bafokeng High School. The old building was then used as a Junior Secondary school and renamed Matale Junior Secondary School (Appendix A No. 3). A sketch plan of Bafokeng High School is given in Fig 1.4.

The planning and construction of Bafokeng High School over 25 years ago illustrates the forward thinking of the Kgotla at that time. Four specialised rooms were provided, namely, science laboratory, library, housecraft room and woodwork room. Two toilet blocks with flush toilets were built. The recreation area had an athletics track, a football ground, netball court, softball ground. Finally a large school vegetable garden was fenced off for the teaching of agricultural science. The first principal of the newly built school was Mr Sifora who gave the scholars the motto "Wena fela" (= Be yourself).

Some ten years later another Junior Secondary school was built at Chaneng and named Mafenya Junior Secondary School. Still others were built at Luka, Kana and elsewhere in the Bafokeng area. At independence in 1977 the Bophuthatswana Education Department took over control of all of these schools from the Bantu Education Department

but little or no change was introduced into the school syllabus.

Fig 1.4. Sketch plan of Bafokeng High School (1986)



All the schools in the Bafokeng region are classified as

"community schools" which means the local community has built them and continues to maintain the buildings while the Department of Education pays the teachers' salaries and controls the syllabus and the teaching.

In the eighties the Bophuthatswana Department of Education introduced a new school structure of Primary (std 1 to std 4), Middle (std 5 to std 7) and High (std 8 to std 10) schools. As a result of this reorganisation Matale and Mafenya Junior Secondary schools became Middle Schools. Kgale Primary School was upgraded to Middle School status and was renamed Keledi Middle School. The revolt of black scholars in South Africa against Bantu education was sparked off in June 1976 in Soweto by a protest against the imposition of Afrikaans as a medium of instruction. The trouble spread rapidly throughout the country and Bafokeng High School was also caught up in the turmoil. Here it was not only the language which became an issue but the fact that many teachers were unqualified and unable to handle matric subjects which provoked the students. The school was completely disrupted for about six weeks in September/October 1976. The school strike of 1976 is recalled by several of the present staff of Bafokeng High School as a

> "bad bad time ... teachers were chased through the bush by angry students ... one gentleman knew he was not able to run fast took shelter in a house ... he was dragged outside and stoned until he was unconcious ... he spent several months in hospital and never came back to teaching ... " (Appendix A No.1).

The school only reopened for the end of year examinations and naturally nearly all failed. Mr. Mantswe, the Principal, promised the students improved staffing for the following year. Due to the same riots in 1976 a private Roman Catholic high school near Pretoria was closed and three of the white staff from that school were available to work in Bafokeng High School as from February 1977. These three belonged to a group known as de La Salle Brothers. They undertook the teaching of maths, physical science, biology, history, geography and English in the matric classes and the school year passed without any serious disruption. The fact that three whites were working under a black Principal was found to be very strange by the local people (Appendix A No.1) because of the apartheid laws of the country which prohibited such an arrangement. It was permitted in this instance because Bophuthatswana was well on the way towards independence by that time. The enrolment during the next four years exploded and the number of students doing maths increased more than five fold as shown in Table 1.1.

Over the past ten years there has been a massive investment of funds by the Bafokeng tribal authority in education and several new schools have been built. At present Phokeng still has only one high school viz Bafokeng High School and the intake comes almost ex-

clusively from three middle schools: Keledi, Matale and Mafenya. Together these four schools make up a well defined educational unit and the present research concentrates on this group of schools in the investigation into mathematics teaching and learning among the Bafokeng people.

Table 1.1. Enrolment patterns in Bafokeng High School

YEAR	NUMBER ENTERED FOR STD 10 EXAM	NUMBER WHO OBTAINED M. CERT	NUMBER WHO OBTAINED S. CERT	NUMBER WHO ENTERED MATHS
1977	42	9	21	8
1978	50	16	26	13
1979	118	29	72	29
1980	161	50	92	46

1.3.2. School problems

Just as elsewhere in Africa the schools in Phokeng may be regarded both as the product of society and as powerful instruments for development and bringing about social change (Thompson 1981 P.131). It can be seen from the short history of schools in Phokeng given in the previous section that there were pressures for change in

the schools from various groups right down the years. For convenience in the present discussion only the groups of parents, scholars, teachers and management will be considered here.

In the last century it was failure of the initiation schools to meet the needs of the times that led Chief Mokgatle to invite the Lutheran mission to Phokeng. This spelled the death of the initiation schools. The need at that time was for reading and writing skills which were seen to be necessary for coping with changes brought about by the coming of the whites. The church schools served the people well until it was realised that reading the Bible and hymn singing was not enough. Young men working in Kimberley and Johannesburg realised they needed to know about money and they demanded to be taught arithmetic. The management in the person of the Rev E. Penzhorn wished to maintain the character of the church schools which were aimed specifically at preparing youngsters for confirmation. The scholars too were hearing stories from far afield which made them also realise they needed a wider curriculum. Many of the parents had themselves worked as migrant labourers and had experienced at first hand the industrial revolution with its machines and organised labour which was rampant elsewhere in South Africa. As a result the school managers found themselves to be in conflict with the other groups and this resulted first in Dedrick P. be's

breakaway private school and second in the eventual setting up of primary schools with a much broader range of subjects though still controlled by the Lutheran church. In the twenties even the church aims were frustrated to some extent when the Rev Spooner arrived from America preaching pentecostalism. He set up another primary school which was based on the tenets of his own version of Christianity and differed from the Lutheran one. It is well remembered by the old people that rivalry and even personal animosity existed between the two reverends (Appendix No. 2).

During this period the Bafokeng tribal Kgotla had also begun to build its own tribal primary schools in Phokeng and in other centres. The forties brought another crisis. The tribal Kgotla realised the powerful influence of the schools and they used the Transvaal education officer Mrs McGregor to fight their case. This lady had a house just outside Rustenburg. She was well loved by the people and trusted by the Chief and the Kgotla (Appendix A No. 5). Mrs McGregor helped in the setting up of tribal primary schools all over the Bafokeng tribal territory and she was also instrumental in the establishment of a secondary school in Phokeng which later became Bafokeng High School.

The pressures continued to be felt and demands from the scholars and their parents for an ever widening curriculum were met as they arose. For example in 1945 the

large house which had served as the secondary school was no longer big enough. A new building was erected on the site of the present Matale middle school to provide classrooms for the increased numbers and to provide training in home economics as demanded by the parents. In 1953 there was a demand for mathematics by the students in the secondary school and a certain Mr. Monari was recruited to teach mathematics. One of the scholars of those years recalls:

> We all wanted to do maths but Mr. Monari refused. He only took a group in Form I who were able to follow maths and he brought them along up through the school with maths as one of their subjects (Appendix A No. 4).

In 1963 a still larger building was required and a library, a physical science laboratory and a woodwork room further expanded the range of subjects available. The demand for more secondary school places was met by opening Matale junior secondary school in Phokeng in the sixties and building Mafenya junior secondary school in Chaneng in the seventies. With the proliferation of schools there now emerged a new problem. An ever widening rift developed between the scholars and their often illiterate parents or grandparents. As a result the scholars tended to become a very independent group and they were hard to control. They accepted school discipline only in so far as they felt it to be just. There have been serious clashes between the scholars and the teachers at Bafokeng High School. In 1976 the stu-

dents rebelled as was described in the previous section. One of their grievances at that time was the number of unqualified teachers who were unable to teach matric subjects properly. That problem was solved in 1977 by the recruitment of three University graduate white teachers. Again in 1985 students rebelled and this time the major complaint was the excessive use of corporal punishment. No real solution has yet been found to this problem. One thing which was quite remarkable in both of these outbreaks was that no parents were involved in the negotiations (Appendix A No. 5).

In recent years there has been an ever increasing awareness among the students of th importance of mathematics for obtaining better jobs and for the pusuit of further studies. In 1977 eight students did maths in the std 10 examination and this number increased steadily as shown in Table 1.1. till there were over sixty students in the maths class in 1986. But as the number taking maths increased so also did the number of those who failed to pass maths in the std 10 examination. The same is true for the standard 7 examination which usually produces twice as many failures in maths as passes. All the students must take mathematics in the middle schools and all must do mathematics in the standard 7 examination. Very few (approx 25%) take maths in the high school. Nowadays there is a move from parents and from the Department of Education to have all students do maths at

least up to std 8 level. The schools cannot cope with this demand firstly because there are not sufficient suitably qualified teachers, and secondly because the std 8 syllabus is geared for students who will need maths at University and there is no provision for the needs of students who want to do maths for other reasons. It seems that at this time one of the most serious sources of conflict in the schools is therefore mathematics teaching and learning. Parents want to know why their children are not allowed to do maths in the high schools. Teachers reply that a minimum of 40% pass in std 7 is essential but most of the students have not reached this standard and therefore won't be able to cope with the std 8 maths syllabus. Then parents want to know why their children fail in std 7 and no one seems able to answer that question. If a std 7 teacher attempts a partial answer such as telling the parent that your child is not bright enough, the indignant parent will point to another child who may have passed and claim that his own child is as bright as that one. Much confusion exists in the debate and there is a real need for research into success and failure in mathematics among students especially at the standard 7 level. The present research was undertaken for this very purpose - to shed some light on the real situation and to attempt to broaden our understanding of the problem. In the next section there is a description of

how the problem was tackled but firstly it is necessary to outline what precisely the problem is.

1.4. The Present Research

1.4.1. The problem outlined

There are two external examinations done in the secondary schools in Bophuthatswana. At the end of middle school, students do the std 7 examination which is set and controlled by the Bophuthatswana Department of Education. At the end of high school, students do the std 10 matric examination which is controlled by the Joint Matriculation Board of South Africa. All the students do maths in the std 7 examination but only those who chose it do maths in the std 10 examination. The pass rate in std 7 maths is very low. The national average for Bophuthatswana over the years '86 to '88 was 35,0%, 35,3% and 30,8% respectively (Bophuthatswana National Education Report 1989). But this does not give the full picture. In Bafokeng high school there are almost 300 pupils enrolled in std 8 classes. The symbols obtained by this group in the std 7 maths exam are summarised in Table 1.2. The distribution of marks in Table 1.2. approximates closely to another set of figures for all the schools of the Tlhabane circuit of education 1985 and given in Chapter 2 Table 2.2. It can be seen from Table 1.2. that 180 pupils scored less than 40% in the examination and only 95 pupils scored 40% or

over.

Table 1.2. Std 7 maths symbols of Bafokeng H.S. pupils

SYMBOL	MARK %	NUMBER	PERCENTAGE
A	80 +	0	0
B	70 - 79	1	0,4
C	60 - 69	2	0,8
D	50 - 59	19	6,9
E	40 - 49	73	26,6
F	33 - 39	63	23,0
G	25 - 33	46	16,8
H	0 - 24	71	25,5
TOTAL		275	100%

In most schools in South Africa 40% is taken as a pass mark for a subject. It must be concluded that large numbers of students are unable to reach the mathematics objectives set for them at std 7.

Margaret Donaldson (1978) writes that the common sense explanation and one that is often heard in such a situation goes like this:

> ... the inevitable conclusion ...
> is that either large numbers of students are irredeemably stupid or that the teachers are not doing their work (ibid P.15).

In his capacity as a maths teacher in Phokeng the present researcher has attended several meetings where this problem of the difficulty in learning maths has been discussed. What follows is a summary of such meetings held from 1984 to 1989 in the Tlhabane circuit. Invariably the debate about mathematics reduces itself to a discussion of the poor performance of the students in the maths examination at std 7 and std 10 level. The whole focus is on improving the pass rate. For example L.G. Holele, 'Bophuthatswana Minister of Education, in his 1987 budget speech noted the large increase in money voted for education over the previous five years. In 1982 it was R66 million and in 1986 it had jumped to R186 million. He then referred to the larger number of failures in the standard 7 and standars 10 examinations and questioned whether the expansion in funds was producing an equivalent expansion in quality education (Popagano 1987). The viewpoint of the department officials and school inspectors is that the std 10 teachers are not doing their work because so many std 10 pupils are failing maths. For example at one meeting the following figures were quoted: In 1988 approx 17000 students entered the std 10 examinations in Bophuthatswa- but only 3 000 (i.e. 18%) did maths. Of this number only 800 passed and most of them had poor symbols. Hence approx 5% of the total std 10 group passed maths.

This is not acceptable to the department of education, and the reasons given include:

(i) Administrators in the University of Bophuthatswana (UNIBO) complain that they cannot recruit students with sufficiently high symbols in maths i.e. D (= 50 - 59%) or better to enrol for the science courses.

(ii) In the Teacher Training Colleges there are very few students doing maths in the secondary teachers diploma classes. The figures given indicate a mere 26 students for the five colleges in Bophuthatswana.

(iii) Proposals for setting up a medical university in Bophuthatswana are in jeopardy because sufficient students with adequate passes in mathematics are not available.

Not suprisingly the teachers have quite a different perception. Their view has been expressed at numerous teachers' meetings and in magazine articles; for example Lehobye criticised the mass production of ill equiped pupils in Bophuthatswana who aquire knowledge through rote learning. He alleges that "inflexible curricula which overplay the importance of end of year examinations" is one of of the root causes of the problem (Lehobye 1987). The thinking of the high school maths teachers, as expressed at meetings, runs like this:

(i) The products from the middle schools are very poorly prepared in maths. Their symbols are very low

and many of them have never done whole sections of the middle school syllabus such as graphs, geometry etc.

(ii) The blame for the poor matric maths results is always put on the heads of high school maths teachers who are accused of being lazy, not giving students sufficient work to do in school or at home, and not correcting the homework and not motivating or encouraging the students etc. The high school maths teachers reject these allegations as not being true.

(iii) There is no consultation with the teachers about the syllabus content. It is constructed by people in authority and it is imposed on the schools. Then the teachers are blamed because the students are not able to learn the syllabus.

(iv) Maths is very difficult compared to other subjects and therefore proper guidance is needed to direct students into suitable subject choices. Those who are unable to achieve a pass in std 7 maths mustn't do maths in high school. The experience of one teacher highlights this issue:

> In our school out of a hundred students who applied for admission in January only six had obtained symbol E or F in the std 7 maths. The principal said we couldn't have a class with only 6 students doing maths so another 36 students who had symbols G and H in maths were bundled together to make a class of 42. I am now trying to teach std 8 maths to this class and it is impossible.

(v) There is a huge gap between the maths attainment

of the students entering std 8 and the overloaded maths content they are expected to master in that year. If the syllabus is reduced then this leads to a further lowering of standards.

(vi) There is a preoccupation with examinations. One teacher expressed this preoccupation thus:

> It is an undeniable fact that to a great extent a successful teacher is associated with the performance of his or her students at the examinations ... thus passing examinations has become the principal aim of teaching (Assan 1986).

Most of the time at the meetings and courses is wasted talking about the number of failures in the maths examinations and little or no time is spent on how to improve maths teaching and learning...."We never talk about new methods of teaching different topics or about how we could increase the students' interest in mathematics."

As a group the middle school maths teachers tend to be less vocal about their own viewpoint. During courses most of the time is taken up with learning the std 7 maths content. As a body they seem less sure of their maths than the high school teachers. Many of them say they have been forced to teach maths since no one else was available in their schools. Others point out that they are really primary school teachers who have been transformed into middle school teachers because their school was upgraded but they received no special training to prepare them for this new work. The few who do

reflect on the maths problem express a viewpoint somewhat as follows:

(i) English is the medium of instruction for maths in the middle schools but many of the children cannot speak, read or write English fluently enough to enable them to follow maths classes conducted in that language.

(ii) Many of the students are unable to do even simple arithmetic calculations, they don't know their tables and they cannot solve even simple word problems.

(iii) There is a very wrong attitude towards maths in the middle schools. Most of the students think it is very difficult and they are afraid of maths.

(iv) Some of the students are staying with their grandparents while their parents are working in Johannesburg or elsewhere. They have little money and they can't buy books. So the schools have been providing text books for the past 3 years. Sometimes you may find a student who passes the whole day at school without eating any food. There is no electricity in the homes and it is not easy to study at night using only a candle for light.

The three groups referred to in this section have very different perceptions of the problem which they would all describe in terms of "the problem of maths in our schools". The school inspectors and department of education officials are concerned with manpower needs of

the country; the high school teachers are occupied with the overloaded maths syllabus for which the std 7 work does not prepare the students properly; the middle school maths teachers appear to be more in tune with the socioeconomic and other difficuties of the children. It is clear however that there is a great deal of confusion and frustration on all sides and it is urgent that key issues in the debate need to be investigated by scientific research. Some of the issues that emerge are:

a) What do people mean when they speak about "maths"?
b) What is the prevailing attitude to maths in the schools?
c) Is there a relationship between socioeconomic level and maths performance?

An accurate description of the school situation is essential and in this connection there are a number of questions which must be posed including the following:

d) What actually happens during a maths lesson?
e) How bad really is the maths attainment of the students e.g. are there fundamental concepts of number and operations which are not properly understood?
f) Is the medium of instruction a compounding factor?
g) Are there cultural or other factors among the Bafokeng which make it difficult for the students to learn maths?

Only when this work has been done will it be possible to understand the real nature of the problem and hopefully

begin to work on solving it.

1.4.2. Research requirements

From the outline given in the previous section, anyone undertaking to research the problem described there would need not only basic research skills but also certain personal and other qualities due to the delicate nature of much of the research. Among these qualities would be: personal experience of maths teaching in Phokeng; acceptance by teachers; rapport with students; fluency in Setswana; familiarity with customs and traditions of the Bafokeng; practice in the use of interview as a research instrument.

The present researcher has been working in Bafokeng high school since 1977 and is an experienced maths teacher. He has been working in a voluntary capacity in adult education classes and in upgrading courses for middle school maths teachers. He is known to most of the Principals and many of the teachers in the schools of the Bafokeng region. He has a moderate fluency in Setswana. He has carried out previous research into factors relating to the drop-out problem in schools which involved interviews that often probed deeply into personal and family matters. He has a keen interest in the problem because of personal observation and discussion with the people involved. He is imbued with a Christian spirit which views all persons as entitled to equality and

basic freedom and he believes in the essential goodwill of all involved in the educational process.

1.4.3. How the research was carried out

Once the broad outline of the problem had been identified as given in section 1.4.1. above then it was necessary to explore the literature and find out if there were guidelines from previous research that would direct the present study. The works of Dewey, Piaget and Witkin were studied but it was more particularly the writings of people in the field of maths education such as Bruner, Dienes and Skemp that were found to be helpful. A whole area of research into how children actually think and do maths has been opening up in recent years and much of this material has been reviewed by such authors as Lesh and Landau (1983) and Dickson et al (1984). Culture and mathematics has been the subject of considerable interest due to the work of Gay and Cole (1967), Cole et al (1971) Bishop (1983) etc. and several reports on how this relates to black people in South Africa have been published by the Human Sciences Research Council in Pretoria. Several maths projects both local and overseas were studied and the implications for the present research were teased out. The literature survey is presented in Chapter 3. One of the most useful things to emerge from this survey was a methodology which is variously described as "anthropological"

(Nisbet 1980, P.6) "interpretive" (Cohen & Manion 1980,P.25) and "illuminative" (Hamilton 1976,P.39). In brief this method involves firstly a broad survey of the scene during which a great number of informal non-structured interviews and discussions were held with teachers, students and other interested parties in order to determine what their own perception of the problem might be. Nisbet suggests:

> The descriptions used by different participants to explain their experience provide an exploratory tool; and thus theory is grounded in the every day life of the people who are being studied. Illuminative evaluation uncovers the nature of what has happened (Nisbet 1980, P.6).

At this stage copious notes were made by the researcher during meetings, seminars, inservice courses as well as interviews and discussions. National education reports and other official documents were consulted and school exam schedules were examined. Resulting from these first steps a research design was constructed and a pilot study undertaken in 1986 as described in chapter 4. The outcome of this pilot study was the realization that the largely correlational design was inadequate and another approach was needed to get to the root of the problem. Statistical analysis of factors relating to maths performance was not sufficient and it was necessary to carry out indepth interviews with a sample of students which is the substance of chapter 6.

Socioeconomic and cultural factors emerged from the

literature as being most clearly related to school achievement but it was necessary to examine how these affected maths in Phokeng. It was further necessary to explore what these factors really meant for the Bafokeng and how they influenced perception of mat questions given to the students in the form of problems to be solved. Also an analysis of the Se' ' language was carried out to see how it too affected maths understanding. All this is reported in chapter 7. An important part of the illuminative method is the triangulation technique which contributes to both validity and reliability of socio educational data. An account of how maths is actually taught in the ' ' classes and how this is related to the performance students in maths is given in chapter 8. Chapter 9 examines other factors, loosely termed "personal factors" in the literature. This chapter includes self-concept and cognitive style among others, and investigates how these affect school achievement among the Bafokeng. Finally chapter 10 has a summary of the major research findings and some of the implications for the future are discussed.

In the next chapter the key concepts "mathematics" and "success in mathematics" will be discussed.

CHAPTER 2

The Problem Outlined

2.1. Introduction

Mathematics as it is now taught in our schools is an invention of mankind and historically its roots can be traced to many different cultures. The need for mathematics arose from practical situations like keeping track of animals in a herd. This was probably done by simple visual perception when the numbers were small but with larger numbers people began to use fingers, stones and tally sticks. Number was abstracted from physical objects and as early as 3 000 B.C. symbols were already being used to stand for numbers and the simplest arithmetic operations were understood (Russell, in Wolff, 1963, P.163). It is likely this development came about because of trading, business, taxation and government requirements. A practical form of geometry developed because of needs in surveying agricultural lands after seasonal flooding in the Nile basin (ibid, P.41). The word "geometry" means "measurement of the earth" (ibid). It wasn't very long until fascination with the figures - circles and chords, triangles and angles - became the object of interest and study and when Euclid, living in Alexandria 300 B.C. made a collection of the then known geometry it ran to 13 books (ibid, P.43). Historians

trace the origins of the decimal system to India and about the eighth century Arabian scholars borrowed "zero" and the decimal system and made it their own, and they invented what we now call "algebra". It was only centuries later that Europe began to borrow from the Arabs but once the process got started in Europe it gathered tremendous momentum. In the 17th century there was a great explosion of mathematical activity in the West: Napier developed logarithms, Descartes the analytic geometry, Pascal the theory of probability, Newton and Leibnitz, independently, devised the calculus. By this time it could be said mathematics had become an integral part of Western culture. Initially mathematics in Europe was linked to commerce, architecture, engineering, astronomy and the sciences but then it took off into abstraction of number and operations and systems and became divorced from real life requirements (Vergnaud 1983, P.127).

For many, mathematics became the handmaid of science because of its ability to summarise so precisely natural laws in terms of mathematical models. For example Robert Boyle spent years experimenting with glass u-tubes and mercury, often frustrated by clumsy Irish peasants who were called in to hold the large apparatus (Robert Boyle in Hurd & Kipling 1958, P.260), but he was able to formulate his law relating pressure to volume in a simple mathematical equation: $P.V = K$

For others mathematics was the queen of sciences and while they acknowledged its usefulness this aspect became irrelevant for them and an invention like "$i = \sqrt{-1}$" was considered wonderful in its own right.

There is no material available on the early beginnings of mathematics among the Tswana although some archaeological research in the Magaliesburg district has uncovered what appears to be "town plans" carved on rocks dating back several centuries (Steel 1988). The smelting of iron was a highly developed skill in this area since the 10th century (Mason 1983, P.261) and there must have been some method of measuring the proportions of each rock used in the process. The ability to construct rondavels and the proliferation of geometrical designs and patterns for decoration as well as the complicated numbers-board game traditional to the Tswana all point to some level of practical mathematics. It seems illiterate herdsmen still use stones to keep records at the cattle post even to this day (Appendix A No. 2). but the old people say any herdsman worth his salt can recognise, just by looking, when an animal is missing. He will notice the brown one is not here or the one with the crooked horn is gone (Appendix A No. 6).It is not clear however whether there was any abstraction even of the concept "counting numbers". In Setswana numbers cannot stand on their own as nouns, they are always used as adjectives qualifying objects as

for example "setilo se le sengwe" translates "one chair" but "monna a le mongwe" is "one man" and the suffix "ngwe" signifies the oneness in each statement.

Interest in modern mathematics can be seen in stories dating back to the early part of this century. One story refers to the dispute in 1912 between a local teacher D.C. Pitsoe and the Lutheran moruti Rev Penzhorn about expanding the syllabus of the confirmation schools to include arithmetic (Appendix A No. 2) as related in chapter 1.

Even before the opening of the Platinum mines on Bafokeng tribal lands the influx of technology had brought rapid interest in mathematics and it is now taught in all schools up to standard 7 level. The teaching and learning of mathematics in the schools is very uneven and this has contributed to the practice of mobility among the students moving from one school to another because they hear "the students in that school do very well in maths". While there may be some truth in such statements nearly all the schools experience more gross failures than good results. For example in Bafokeng High School in 1986 there were five students who had come from places more than 50km away pursuing good results. At the end of that year one scored symbol A (80% or over) two scored symbol B (70% or over) but the other two failed to pass mathematics.

The problem undertaken by this research is to examine

the success and failure in mathematics among standard 7 students in the Bafokeng region of Bophuthatswana, searching for factors contributing to either. Chapter 1 has given a historical summary of the social and educational situation of the Bafokeng and here in Chapter 2 key concepts in this research will be clarified. Section 2.2. details the problem; Section 2.3. discusses what is meant here by the term "mathematics"; Section 2.4. deals with the criteria for "success and failure".

2.2. Statement of the problem

The aim of this research is to study the performance of a group of standard 7 students in mathematics by first identifying factors which are associated with success and failure in mathematics and then analysing how each factor contributes to this success or failure. There are several reasons why it is thought this topic needs to be investigated. For convenience these reasons will be grouped under the headings: (i) personal observation (ii) teachers' opinions (iii) exam results of students (iv) HSRC Reports (V) MATIP activities.

(i) Personal observation during the course of ten years as a mathematics teacher at Bafokeng High School has forced this researcher into recognising that mathematics presents serious difficulties for Tswana students and teachers in this region. Students find mathematics very difficult and they describe it as "a very tough subject

which needs one to concentrate a lot". Even though they spend long hours battling with the text book and doing exercises they are completely thrown off by even minor changes in the framing of a question. It appears their understanding is purely instrumental (Skemp 1979, P. 259) they can learn rules but don't grasp their meaning and they are unable to apply their mathematics knowledge in new situations. A few examples from a maths class will illustrate this point: (a) 2 x 3/4 = 6/8 (b) 20 + 3 x 16 = 76 (c) T1 = 2, T2 =5, T3 = 8, Tn = 11 n =11. Often the problem becomes more glaring in a science class when students have to do simple calculations such as "2 moles reactants yield 4 moles products, how much product from 0,5 moles reactants?"

But in maths class also, application is always troublesome. Students who have "done" Pythagoras' theorem and numerous numerical exercises are unable to find the length of a ladder touching a wall given the required measurements along the ground to the foot of the ladder and up the wall to the top of the ladder. One peculiar aspect about teaching mathematics to Tswana students is that almost all of the students find geometry extremely difficult whereas they seem to manage trigonometry and vectors fairly easily. The syllabus in mathematics seems to be away beyond what most students can cope with and the text books are so incomprehensible that students no longer feel urged to buy them at all.

In Bafokeng High School 1988 only 15 out of 45 standard 8 maths students had bought the maths textbook. The different standards used in the various subjects are evident in what is expected of students in a given year. In English language all that is required i that they can remember the general plot of a fairly small novel such as "Mali and the boy" whereas their mathematics text has several hundred pages and they are expected to know every page in detail and to be able to apply it to completely new problems. Basic arithmetic calculations and following rules does not seem to be the major difficulty but deciding which operation to use and being able to discard one rule or adapt another to solve a problem does seem to be very hard for most students.

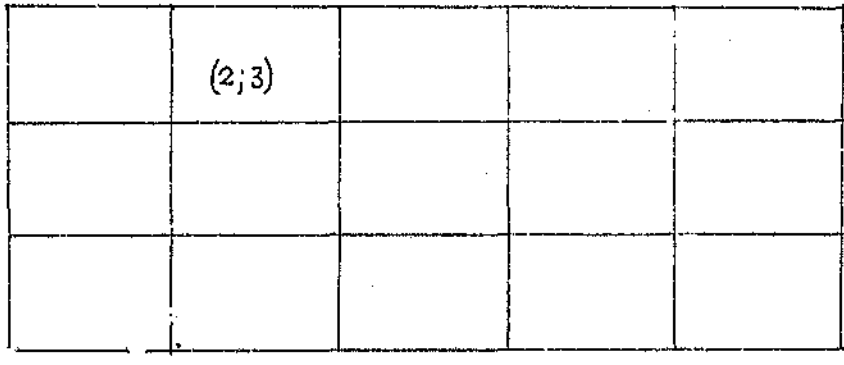
(ii) Concern about mathematics teaching and learning is a common topic among teachers in Primary, Middle and High schools, in the staff room and in casual conversation. Sometimes they will say:

"I cannot do mathematics" or "I failed mathematics in school" or "I wonder why our students don't know mathematics". And often some or all of these comments are true. This researcher has seen teachers unable to find the average mark for a class test or even total a long list of marks; and the common method of doing sums like 47 x 20 is repeated addition - adding 47 and 47 to get 94 then adding another 47 and so on twenty times. The use of pocket calculators has relieved this problem

in recent years and teachers seem to learn readily how to use calculators for straightforward calculations. As an organiser of middle school inservice courses for mathematics teachers, the poor ability of some teachers in mathematics has become evident to this researcher. Most of the time in these courses is taken up with teaching the content of the standard 7 syllabus and very little time is available for methods. For example when dealing with " y = mx + c " (section 5.5.5. of standard 7 syllabus) this researcher spent a full hour helping teachers to draw graphs of this kind: $2y + 3x - 4 = 0$ and while some understood the process and quickly moved on to the generalised expression for a straight line graph most of the teachers had only a vague notion that "m" was connected to something called "gradient" and "c" was "something else" and neither symbol was understood in the sense of Skemp's (1979) relational understanding. At the same course when reviewing the system of naming ordered pairs in the cartesian plane it was found teachers had some difficulty. In order to clarify the system they were asked to look at a stack of shelves divided into cubby holes lining the back of the room. Few teachers were able to identify a cubby hole from the label (2;3) or whatever but they caught on quickly and there was so much enjoyment and laughter during this "game" that it seemed some teachers were experiencing reality in mathematics for the first time in their

careers. Some coins were placed in the shelves as rewards for successful identification and when the last label led to a find of a scrap of paper with "madi a fedile" (=the money is finished) written on it there were howls and shrieks of laughter all over the room.

Fig. 2.1. Arrangement of library shelves at back of classroom



The point being made is that the teachers had never experienced this section of mathematics in any context other than that of X and Y axes as used in the text book and they were unable to apply their knowledge outside that very limited framework. In fairness it must be added that many of these teachers had been trained as primary school teachers and when the middle schools were introduced in the eighties they found themselves having to teach at Junior secondary level. It seems so obvious that the progression should be from physical situations to abstracted theory that one wonders at how the reverse

could have become acceptable practice in the schools. It seems the syllabus at all levels is so overloaded that teachers and students haven't time to deal with it properly and they resort to cramming. In some ways the situation parallels the Kpelle schools described by Cole et al (1971, P.49-51). These authors suggest the child in such a confused school environment is forced to adopt rote learning i.e. to pick out certain salient features of the situation and simply memorise them (ibid P.51). In their anxiety to complete the syllabus the teachers cannot afford the time it would require for mastery learning. This is true for all content subjects but especially for mathematics where it is essential to build up understanding in a stepwise manner. If a basic concept is not properly understood then the subsequent work in that section cannot be meaningful.

(iii) Examination results are considered to be very important in Bophuthatswana and in each circuit there is competition among the schools to be recognised as the school with the best results. Each year a list is circularised giving the percentage passes and failures in the standard 7 and standard 10 examinations. The 2nd National Education Commission Report of 1986 stated that maths was one of the "real problem areas" in the middle schools judged from the performance of students in the examination of 1985 (P.55). Results from the three middle schools which are associated with Bafokeng High

School show just how bad it is;these results are given in Table 2.1.

Table 2.1. Standard 7 maths results for 1987

Year	School	Number Entered	Number Passed	Percentage
1987	Keledi	317	126	24,8%
	Matale	182	51	23,6%
	Mafenya	126	35	28,4%
	National	34166	14666	26,4%

These figures were the actual numbers before adjustment. According to the official marks sheets these figures had been increased by up to 30%.

In 1984, the last year of standard 8 public examination there were 357 Bafokeng High School candidates who did maths in the examination and only 24 i.e. 7% scored 40% or over.

(iv) During the seventies the Human Sciences Research Council launched a comprehensive research programme at the request of the Mathematical Association of South Africa.

That body had realised at its 1970 Congress that there was a need to implement changes in the mathematical syllabi to enable the compilation of a differentiated syl-

labus for those unable to cope with the existing one. It must be remembered that in South Africa there are four separate education sub-systems, one for each of white, Indian, coloured and black race groups (Ruperti 1976, P.46). Act No. 47 of 1953 (the so called "Bantu education act") handed over control of all African education in RSA to a minister of Native Affairs (Rose and Tunmer 1975, P.258). This act firmly entrenched the priciples of "apartheid" in the education system and set the tone for educational research in the sixties and seventies. The Mathematical Association was merely commenting on the situation of mathematics in the black system - large numbers of students were not doing mathematics as a school subject and those who were doing mathematics were failing miserably in the public examinations.

A broad based report was prepared by Groenewald (1976) which studied the traditional cultural background of the "Bantu" child in order to determine what aspects of it were related to the "ineffective actualization of intelligence". Futher reports by Van den Berg focussed on the "Black man's mathematical ability" (1978) and the "means of promoting Black pupils' insight into mathematics" (1980). Such concern, shown by the allocation of research funds and personnel demonstrates that there was an awareness in the RSA of the problem which mathematics presented to black students. It was seen that if

the vast pool of black labour was to be effectively tapped for middle management in industry then drastic changes were called for.

(v) The same difficulty was evident in the independent homelands. At the request of the governments of the developing states the University of the Orange Free State set up a special section named MATIP at Bloemfontein and funds were soon made available from the industrial sector to run a very efficient and very worthwhile project. MATIP has organised and conducted courses as well as developing materials for teaching maths. It also aims to co-ordinate and promote research in the field of maths and science in black schools.

A survey of the literature available at both MATIP and HSRC and the research done to date is presented in the next chapter, section 3.4.4. From all this it can be seen that mathematics is a problem and while already considerable research has been done, most of it by large scale surveys, there is an urgent need for an in-depth study of how Tswana students learn mathematics and what enables some to succeed while most others fail so dismally.

2.3. The concept "Mathematics"

The concept "mathematics"is not an easy one to define because the word may be used in several different

senses. For example different people will use this word when they wish to refer to (i) the subject taught in schools (ii) what occupies the time and energies of researchers in higher mathematics at 3rd level institutions (iii) a branch of philosophy (iv) the abstract formula which provides a model for a scientific law. It is easier to say what maths does than to say what maths is.

Groen & Kieran define school mathematics, which is what concerns us in this research, as consisting of a set of tasks (what children are taught and required to do) and a set of processes (what children actually do in performing these tasks) (Groen & Kieran 1983, P.353). This viewpoint represents a shift in educational research away from the more abstract position set out by the 1974 report of the English Mathematical Association. This report describes mathematics as "an attitude of mind not as a collection of topics and techniques" (P.1). It regarded pattern as the "core of mathematics", and within the general theme of pattern number was then picked out for detailed discussion because "number is the mathematical model of greatest use in everyday life" (P.5). The Bophuthatswana mathematics syllabus describes mathematics in the following terms:

1) it is an external body of knowledge produced by man;
2) it is a means of communication using symbolic notation;

3) it is an instrument for predicting outcomes of events with precision;

4) it is a collection of skills necessary for adult life, employment and further study;

5) it confers the ability to make estimations in measurement. (Mathematics in the Middle Schools, Bophuthatswana, 1985).

It is agreed that whatever else, mathematics has something to do with knowledge. Michael Young (1971) presented two opposing views in trying to answer the question: What is knowledge?

(a) Knowledge is an external reality existing in its own right independent of man's mind. Such knowledge is distributed through well-insulated subject hierarchies. This is a static concept of knowledge.

(b) Knowledge is a product of man's interaction with the envirorment and with other people. It is within the mind. It is the way a person organises his experiences in a meaningful structure (Beard 1977,P.53). Some ten years before Young, Bruner (1960) presented similar models with regard to mathematics from his observations of a ten-year old playing with snail shells by putting them into rectangular arrays (ibid P.126). This child discovered a lot about prime numbers, he says and then he goes on to speak of mathematics in terms of mental development which involves the construction of a model in the child's head, an internalized set of structures

for representing the world. The opposing view of mathematics is that of a body of external knowledge and Bruner suggests this is often what is found in schools:

> Mathematics is a logical discipline and it has certain rules which must be learned and applied to nonsense problems in order to get a correct answer (ibid,P.130).

Bruner does not deny this second idea as being untrue but he does resist the attempts made all too often to impose the latter on the former. He says "this is not sound education, it is not education at all". He advocates a spiral model wherein the mental constructs of an individual child developed by interaction with his enviroment are enlarged and built upon so that eventually he can internalize these new ways of dealing with his situation (ibid). Skemp also sees mathematics both as a body of knowledge (external) and a collection of schemata (internal). What he means by a body of knowledge is a conceptual structure shared and agreed by a number of people such that all of it has been at sometime tested against actuality by someone (Skemp 1979,P.30). Within each individual, mathematics can be regarded as a Type 1 theory of a unique kind (Skemp 1982, P.187) and elsewhere he explains this as a highly developed mental plan for dealing with the physical environment (Skemp 1971, P.17).

Dienes, like Skemp and Bruner, condemns what he calls "the average maths lesson" as being based on a stimulus-

response theory of learning and it usually degenerates into a conditioning process which is aimed at yielding "correct answers" to given stimuli (Dienes 1967, P.137). Dienes thinks of mathematics as a structure of relationships which are communicated from one person to another by formal symbols:

> By mathematics I shall therefore understand actual structural relationships between concepts connected with numbers (pure mathematics) together with their applications to problems arising in the real world (applied mathematics). The learning of mathematics I shall take to mean the apprehension of such relationships together with their symbolization, and the acquisition of the ability to apply the resulting concepts to real situations occuring in the world (ibid).

To summarise then there is agreement that mathematics is

(a) a body of knowledge whose content is structure (Bruner), relationships (Dienes), cognitive maps (Skemp);

(b) a means of communication using symbolic notation;

(c) something devised by man interacting with his environment and therefore purposeful;

(d) something which is learned in stages which build upon each other successively.

The stages referred to in (d) here correspond with different levels of abstraction and are based on Piaget and applied here to four levels of middle school mathematics:

Level 1: children can manipulate objects and do simple calculations based on physical objects which are

present.

Level 2: operations can be carried out with "objects" which are not actually present but visualised in the imagination.

Level 3: concept of number is abstracted and the children can do the operations of addition, subtraction, multiplication and division using only symbols for numbers and with no reference to concrete objects physically present or imagined.

Level 4: using numbers as "objects" the operations are abstracted and children can now carry out operations on variables represented by letters in algebra and they can think abstractly and deal with geometrical figures.

The same levels apply to geometry - level 1 children use cut out squares, circles etc. for handling and making patterns, level 2 they imagine these figures and so on till at level 4 they can deal abstractly with geometrical problems.

In this research it is hypothesised that levels 1,2,3 above have been rushed through and no enough time has been devoted to them, the children have been plunged straight into level 4 because the syllabus demands it and not enough consideration has been given to whether the other stages have been successfully completed or not.

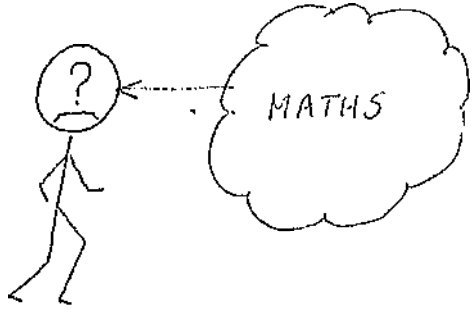
From another point of view altogether mathematics may be taken as the school mathematics curriculum and for the

purposes of educational research This simple definition is the only possible one to use in many instances (e.g. Coleman (1966) in America and Minkowich et al (1982) in Israel).

From the literature it appears that there are three main models of mathematics expressed or assumed in various maths projects, these are:

1) Reification Model - mathematics is something outside of the student. It must be learned because there is a certain kind of magic quality about it which enables one to pass examinations and get a good job. This is the model assumed in the Lesotho Mathematics project at it is what Bruner & Dienes condemn, as has been pointed out above.

Fig 2.2 Diagram to illustrate Reification model



2) Instrumental Model - Mathematics is an external instrument for dealing with the enviroment. For some students this environment is real in the sense that it con-

responds to his own experience whereas for the unsuccessful students the environment is an artificial one created by the teacher or the textbook or the examiner. This model underlies the Caribbean Maths Project and Mathematics for the Majority. In a sense too the construction of a "concept tree" aimed at in Hart (1981) indicates this model. The word "instrumental" is borrowed from Skemp (1976).

Fig. 2.3. Diagram to illustrate Instrumental model

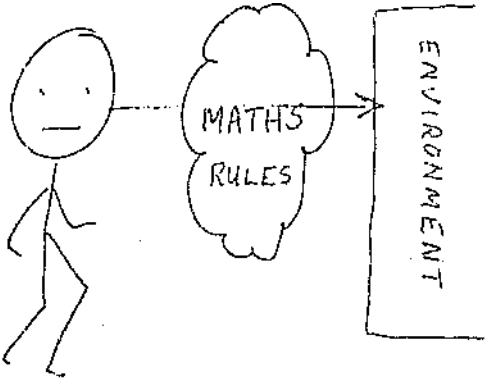
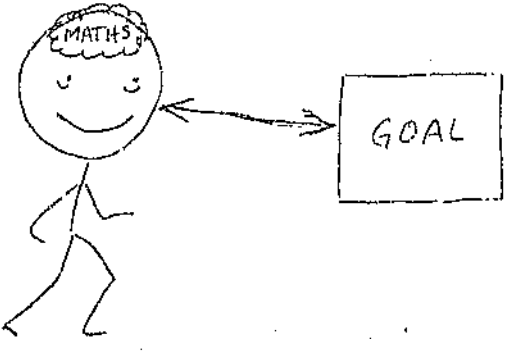


Fig 2.4. Diagram to illustrate Interaction model



3) Interaction Model - Mathematics is a system of mental structures which are internalised as schemata and enable the student to attain a goal state which he perceives to be meaningful. This is the model advocated by Bruner, Dienes and Skemp as being the ideal.

It is not clear whether Gay & Cole (1967) view mathematics as being part of the individual's schemata or as part of the external environment. In one sense they seem to be highlighting a conflict which was beginning to trouble the Kpelle. These people have schemata for dealing with their world as they experience it. Mathematics has no place in these schemata if we limit our use of the word to "western mathematics". But the world as the Kpelle know it is changing, and they now need "western mathematics" to enable them to cope with the new situation.

The model which seems best able to describe mathematics for the Tswana students and teachers is a combination of 1) and 2) above. They regard mathematics as a number of techniques for obtaining correct answers to problems which appear in textbooks and examination papers. The two local mathematics projects described in the next chapter in section 3 assume model 1) above.

In this research mathematics will be taken to mean the standard 7 mathematics syllabus of Bophuthatswana considered from the aspects of:

(i) Content - certain structures or knowledge content

like the Euclidean theorems

(ii) Skills - certain manipulations and calculations like factorization, drawing graphs etc.

(iii) Application of both (i) and (ii) to problem solving.

The discussion in the proceeding pages shows that Dienes, Bruner and Skemp advocate the interaction model. This research will attempt inter alia to identify which model is current among the teachers and students of the Bafokeng region. As pointed out just now there seems to be a reliance on the other two models in the manner lessons are presented and taught and in the attitudes expressed by the students when speaking about mathematics. The usual meaning implied by the term "mathematics" among both teachers and students is one of these: "the maths syllabus" "the maths text books" "the maths examination". Rarely if ever has the present researcher heard mathematics referred to as a way of looking at life or a method of dealing with day to day problems.

But for the purpose of examining success and failure this research will confine itself to the mathematics concept of number which involves firstly the abstraction of number, secondly mastery of counting and thirdly the ability to understand and to use correctly the four basic arithmetic operations of addition, subtraction, multiplication and division.

2.4. The concept "success and failure"

Society has just one criterion for measuring success and failure in school and that is whether the student passes or fails the public examination. As Acton (1980) puts it:

> ... the world judges success by grades obtained in public examinations (ibid, P.166).

In Bophuthatswana all the students take mathematics as a subject in the standard 7 examination which comes at the end of middle school. This examination is set and marked by teachers working in the Bophuthatswana schools. The content of the examination is the standard 7 syllabus which is almost identical with that of the RSA. There is no research available on the validity or reliability of this examination although there is general agreement that the results give cause for concern (Report of the 2nd National Education Commission, 1986, P.55, article 9.2.2.).

In an analysis of the 1984 standard 7 results prepared from the official record sheets shown in Table 2.2. this researcher counted only 72 out of a total of 2 000 i.e. a mere 3,6% who had scored 50% or above in mathematics for the Tlhabane circuit and that after the adjustments given in Table 2.1. These students came from the thirteen middle schools in the Tlhabane circuit which includes the Bafokeng region. According to these results

the majority of the students in the region are well below "average" (taken as 50%). It is obvious that this playing on words is a fruitless task as by definition the majority cannot be "below average" nor indeed "above average".

Dissatisfaction with grading of students by public examination is by no means confined to Bophuthatswana as can be seen from the following quotation referring to GCE results in England:

> There are likely to be problems in a system which is geared to success in exams which are set at such a level that two-fifths of the child population are expected to fail (Rutter et al 1979, P.202).

The authors are here discussing the rights and wrongs of arranging and adjusting examination results on the basis of a normal curve and classifying those who score less than 40% in such an examination as "failures" (ibid).

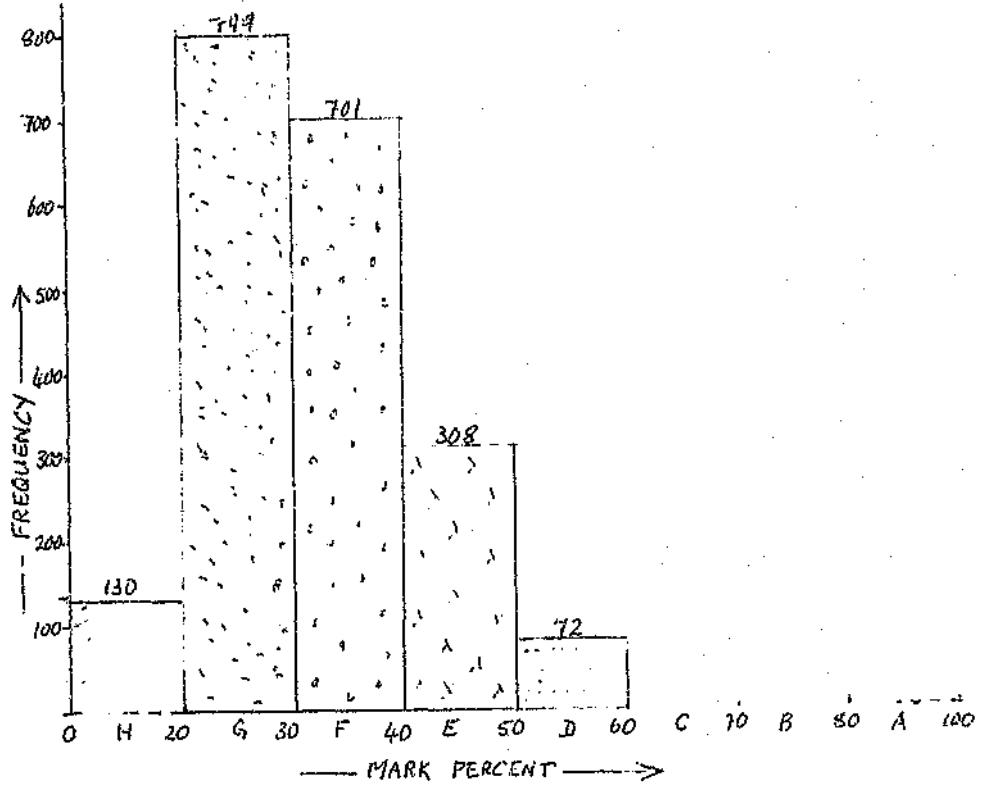
Public examinations do have a function in classifying students on a scale which makes it easy for employers and others to select "good" from "not-good" potential employees but as Acton (1980) pointed out success for one implies failure for another:

> ... so long as employers depend on the educational system not to turn out equally able individuals, but to tell them who is a success and who is a failure, and there is only so much space for success (P.168).

It emerges therefore that at present statistics provide the criterion for success and failure and the decision is made presumably on the basis of normal distribution

curves which are generally standardised for a given population.

Table 2.2. Frequency distribution of maths marks in std 7 examination (1984) Tlhabane circuit



But even this cannot be true for the Bophuthatswana standard 7 maths examination where we find that most students fail, as can be seen from the 1984 results of

the 13 middle schools in the Tlhabane circuit of education given in Table 2.2. Maybe the population (N) is not Bophuthatswana students at all or maybe this examination is not really norm referenced but criterion referenced. There seems no way to find out.

In the evaluation study of Israel elementary schools carried out by Minkowich, Davis and Bashi (1982) the authors describe a serious methodological clash among themselves concerning criteria for success and failure to be used in the research. Davis and Bashi were unable to reach agreement with Minkowich on what constitutes success in mathematics. The former wanted a break down of every item and the use of criterion referenced testing while the latter insisted on norm referenced testing and used composite scores. This version of success was adopted solely because Minkowich was the senior partner (Minkowich et al 1982, P.ix).

Achievement tests (usually norm referenced) are the usual method used in educational research for measuring academic success in schools. For example Rutter et al (1979) used performance in the O level public examinations in their English study; Coleman (1966) and later Jencks et al (1972) used standardised measures of educational attainment in their respective studies of the American system; Minkowich et al (1982) designed tests for their Israeli study on a substantive basis in each subject according to the curriculum requirements and the

expectations of the school.

Other criteria of success found in literature are recognition by peers who may be asked to classify each other as "expert" or "novice" (Riley et al 1983). Riley and associates found that experts have more conceptual knowledge about problem situations and this guides them into more effective and efficient solutions. The successful problem solvers work from elaborated representations of the problem rather than directly from the problem description (ibid). Skemp (1980) takes another approach to success by posing the question: What can we do when we understand something which we could not do before? He provides the answer thus : By understanding we are better able to do three things :(i) to achieve our goals (ii) to co-operate with our fellow-beings (iii) to create, (Skemp 1980, P.1).

Tswana teachers and students have a very pragmatic view of success and failure and it is simply the symbol obtained in the public examination:

G and H (0 - 33%) = failure

F and E (33 - 49%) = pass

D (50% - 59%) = good

C;B & A (over 60%) = excellent.

In the early stages of this research four criteria for success in mathematics were elaborated:

i) pass standard 7 examination with symbol E (=40%-49%) or better;

ii) judgement of the maths teacher that student was good;

iii) student's own perception of himself regarding maths;

iv) choice of maths as a subject in high school.

Those who satisfied these criteria were successful, those who did not satisfy these criteria were judged failures in various degrees. However after some reflection and discussion it became clear that these were not really four separate criteria but simply different manifestations of the first i.e. performance in the public examination. The teachers judged students on the basis of their experience of the public examination (usually quite accurate). The students judged themselves on the results of monthly tests set and marked by the teacher using the same criterion. Finally the decision about taking maths as a subject in high school is normally made by the subject teachers in the high school on the basis of performance by the student in the public examination.

In this research two distinct criteria were used for the two different parts of the research.

(a) For the statistical correlation, the criteria of success and failure were the results of the standard 7 June 1967 examination. Students obtaining symbol D (50%) or over were taken as successful. Those obtaining below symbol F (30%) were taken as failures. The same

classification was used when making samples for the interviews as described in Chapter 5.

(b) Once the sample has been obtained a new criterion was then used on the basis of performance on the five picture problems, in the interview situation. Success was now judged on the students ability to solve the picture problems as follows:

(i) student can select the correct operation;

(ii) student can carry out the computation - knows how to do it;

(iii) student can arrive at the correct answer;

(iv) student can check this answer;

(v) student can complete all this in a reasonable time which was taken as maximum of 8 minutes per problem.

It was hypothesised that these two different criteria were related and students classed as successful on their performance with the picture problems would also be the ones scoring good symbols in the public examination. This was also investigated.

2.5 Conclusion

The main aim of this research remains to investigate success and failure in mathematics among standard 7 students in the Bafokeng region of Bophuthatswana. It has been pointed out here that there are two criteria of success being used namely the standard 7 exam res its

and the performance with the picture problems. It remains to be seen whether these coincide or whether they yield different groups of students and whether it is possible to uncover differences between the groups of successful and unsuccessful students.

Success is regarded ideally as the attainment of model 3) section 2.3. i.e. the ability to use the scheme successfully but it is accepted that this is far from reality of the schools in the Bafokeng region.

CHAPTER 3

LITERATURE SURVEY

3.1. Introduction

Research into success and failure in school mathematics cannot be divorced from the wider school situation. It is necessary to gain some perspective of what has been happening in schools this century in order to appreciate what the present research is all about.

Education is as old as man himself but educational research is a relatively new development. The scientific revolution was well under way by the end of the 16th century but it wasn't until the early part of the 20th century that the scientific method came to be adopted in educational matters. Previously the work was theoretical and even when writing about how to teach in school people like Pestalozzi, Montessori and others worked within a non-scientific paradigm, usually writing from experience which had not been subjected to any form of rigorous scientific testing. Cohen and Manion (1980) quote Mouly's definition of "research" thus:

> ... Research is best conceived as the process of arriving at dependable solutions to problems through the planned and systematic collection, analysis and interpretation of data. It is a most important tool for advancing knowledge, for promoting progress, and for enabling man to relate more effectively to his enviroment, to accomplish his purposes, and to resolve his conflicts. (Cohen and Manion 1980, p.13).

To attempt to bring together a comprehensive survey of all that has been done in educational research would be a fruitless task; even to hope to cover the ground on all that has been done concerning mathematics, teaching and learning would be monumental. Hence some form of selection is necessary and some framework that will show the broad trends in mathematics research is required. This chapter will therefore be presented in three sections:

(i) Psychological movements that have greatly influenced schools.

(ii) School based research into specifically mathematics teaching and learning.

(iii) African and third world research which will include both of these.

3.2. Psychological movements

3.2.1. Psychometrics

For the first half of this century psychological testing dominated the schools. Faculty psychology was quickly replaced by psychometrics. The work of Seguin in France and Galton in England opened the way for Cattell's series of tests which he termed "mental tests" in an article written in 1890 (Anastasi 1968). Spearman attempted to measure objectively what was loosely termed "intelligence" and he defined one fundamental function which he named "g" for general intelligence and a second

factor "s" which was specific to a given activity. Individuals when compared on the basis of their scores on a variety of tasks and intelligence was supposed to be that which was measured, (Chaplin and Krawiec 1960, p.387).

When faced with the question of why some students succeed in mathematics and others fail, the common sense answer would therefore be that the former are more intelligent. Binet developed a method for assessing intelligence on a numerical scale by sampling procedures which enabled him to describe the mental tasks characteristic of a child of a given chronological age (Peel 1956, p.167). Later Merril and Terman used Binet's method to devise an Intelligence Quotient and they were then able to measure the I.Q. of a child and by comparing his performance with that of a carefully chosen sample of others of his own age range they could quantify intelligence, (Jordaan et al 1975, p.751) and (Power 1962, p.598).

These tests became very popular in schools, especially for the purpose of streaming and for career guidance, and there is no doubt that I.Q. tests do have a certain predictive value. On the other hand careless use of the tests and obsession with I.Q. performance may have serious consequences for a child's school achievement and his choice and pusuit of a career (Jordaan et al 1975, p.758).

Perhaps the worst feature of the psychometrics phase was its reification of intelligence. Schofield (1972, p.63) quotes Eysenck's critisism of this tendency:

> Eysenck tells us that the difficulty of defining and measuring intelligence is that intelligence is not a thing but a concept or an idea.

Hamilton (1976, p.12) speaks in a similar manner of:

> ... that research tradition based on the theory and methods of a mental testing and field experimentation of the kind predominantly used by agricultural botanists.

In spite of this a great deal of interest and attention is still given to I.Q. tests although the use of achievement tests to measure scholastic performance and the moderation of the raw scores by taking cognizance of other factors has done much to alleviate the problem. More recently various models based on factor analysis have been used for quantification for example in Verster (1982). Verster used a computer based design to explore reaction latencies in South African subjects. Verster found the processing speed is slower for black males than for white males or white females. It was not possible in his study to account for the difference because variables which might explain the findings were not controlled. Some of the variables mentioned were culture, socio-economic status, education (Verster 1982, P.270).

In Bophuthatswana schools psychometric tests were, until very recently, the only basis for a rudimentary career

guidance service. These tests were administered and scored by teachers appointed by principals in each school but they received no training whatever. The 2nd National Bophuthatswana Education Commission Report of 1985/6 called for a newly structured guidance service that would include: guidance and counselling, educational measurement, remedial teaching and special education (ibid Art 19.1, p.98). This represented a great widening of the role of the psychological services and a move away from mere testing. In the handbook for newly appointed guidance teachers the director of the programme Terry de Jong has this to say about psychometrics:

> ... guidance and counselling is not merely the administration of countless tests which reinforces the popular misconception that the primary function of the Guidance-Counsellor is to offer vocational advice based essentially on meaningless statistics. Psychometric assessment provides a complementary means to other sources and methods available for assisting the student in making an informed decision about which subjects, school and career he/she should choose (de Jong 1988, p.11).

In response to the Commission's recommendations the Bophuthatswana department of education has embarked upon a dynamic project of establishing a school-based guidance service throughout the country. This service was extended to the high schools of the Thlabane circuit of education (which includes the Bafokeng region) in January 1989. The first step was the appointment of guidance teachers in the high schools and the provision

of guidance lessons for all high school students. It is interesting that the newly appointed guidance teachers had no training in psychometric testing nor is such testing included in the work programme set out for them in the first year of operation of the service. The stated aims of the service are:

(i) Group guidance sessions every week for every class.

(ii) Personal guidance for those who need it.

(iii) Provision of consultant facilities for the school on education improvements.

(iv) Community liaison between school and local people.

(v) Cultural expansion (de Jong 1988, p.1).

Guidance and counselling are important issues for the present research because of their impact on choice of subjects made at the end of standard 7 when a student opts for a certain course of study in the high school. Presently in Bafokeng high school there are three groupings of subjects which a student may select namely: Tswana, Afrikaans, English, Biology together with Maths and Science or History and Geography or Bible Studies and Agriculture/Home Economics. Only about 25% of all high school students do mathematics (Bophuthatswana Report 1985/6, p.119). Elsewhere the report recommends selection of subjects should be based on both performance in the subject and career counselling (ibid,

p.122).

Based on personal observation the present researcher can state that students are advised to take maths in high school only if they passed it in the std 7 examination. This research later investigated the suitability of the std 7 examination as a reliable guide for choosing mathematics as a matric subject.

3.2.2 Dewey.

It is difficult to place Dewey - whether among the psychologists who have greatly influenced schools or among the school based researchers. Since chronologically he made his impact in the first half of the 20th century he will be dealt with in this section. Dewey's work is imbued with the "scientific" and he set up an "experimental school" to test his ideas in practice, but he cannot be lumped together with the psychometricians. He was concerned with the child in school and the educative process which has as its aim the disciplined or logically trained mind (Dewey 1910, P.78). He started his career as a schoolteacher and only after teaching for a few years at a country school did he return to University where he majored in philosophy, although his doctoral dissertation was in the psychology of Kant, (Power 1962, p.59).

Dewey criticised "faculty psychology" because it regarded thought as a distinct piece of mental machinery

which could be trained by special exercises - hence arose the idea of formal discipline whereby certain subjects were regarded as intellectual and therefore par excellence were possessed of some form of predestined fitness to exercise the thought faculty (Dewey 1910, Chapter 42). Dewey rejects this claim.

> A subject - any subject - is intellectual in the degree in which with any given person it succeeds in effecting this growth (Dewey 1910, p.46).

The formalism that faced Dewey in the schools of his day might well be compared with the situation in black schools of the 1970's which led to the schools boycotts over the past ten years. One author describes it thus:

> Another kind of formalism resulted from the idea that there was a definite and prescibed subject matter waiting to be mastered, a subject matter that could not be altered by anyone. The idea was deeply ingrained in educational practices. Textbooks were prepared for the various subjects in each of the several grades, and it became the teachers duty to see that the material in the book was covered. Most of the pupil's time was spent in mastering the textbook, a task which meant memorising the details that were touched on in the book. Too often these exercises had little or no meaning for the children. (Power 1962, p.592)

Dewey says the business of education is the forming of skilled powers of thinking. Thought was for him an active process and he suggests that the natural attitude of childhood, namely one marked by curiosity, fertile imagination and love of experimental enquiry, is actually very near to the attitude of the scientist (Dewey

1910, p.iii). He illustrates this scientific method by analysing a complete act of thought in chapter 6 of How we think. The analysis shows that each act of thinking consists of five logically distinct steps as follows:

> Step 1: there is a felt difficulty or perplexity in the individual
> Step 2: its location and definition are thought through
> Step 3: suggestion of possible solutions are con sidered
> Step 4: development by reasoning of the implications of these suggestions
> Step 5: further observation and experiment leading to the acceptance or rejection of the possible solution (ibid p. 60 - 78).

Dewey says the aim of the educative process is to develop the ability to carry out these steps in any particular situation (ibid). In the experience of the present researcher what goes on under the name of "education" in the schools of the Bafokeng region is very far removed from the above. The present investigation tried to find reasons why.

Another aspect of Dewey's work which may help towards an understanding of the problems in black schools in the eighties in the R.S.A. was his efforts to bring democracy into the schools (Dewey 1915, p.7). He was very much aware of the potential conflict between the child, living in a world of personal contacts where affection and sympathy are the keynote and the curriculum which presents material dealing with facts and laws gleaned from all over the world and from every period of history (Dewey 1902, p.5-8). He believed schools were

not simply places where children were prepared for the future; they were more importantly, places where children lived part of their lives as children. This led him to create a school situation in which learners had a great deal of freedom and initiative and self-activity was encouraged. Children themselves would undertake projects and help formulate educational objectives. Personality building and social adjustment were emphasised and the stress was on living rather than on learning (Dewey 1915, p.9).

Among the Bafokeng we find it very rare that the mathematics material presented to the child is such that it has intrinsic interest and that the child's attention is captured spontaneously. Perhaps this is one of the reasons why homework is seen to be such a burden by both teacher and student and to be avoided if at all possible.

Dewey writes about what is likely to happen in such a situation. He says the teacher may attempt to provide extrinsic motivation such as offering rewards or else will report to counter-irritants such as low marks, personal disapprobation or probably will use both these methods (Dewey 1915, p.48).

A feature of the schools in the Bafokeng region is the over-reliance on corporal punishment as a means to force students to do their school work and homework. Perhaps if the subject matter presented in school was more mean-

ingful for both teacher and student this excessive use of corporal punishment could be reduced. It was therefore important for the present research to examine the home lives of the students and especially their socioeconomic circumstances and their cultural beliefs. Finally for Dewey education is a wonderfully alive and active experience. It is neither a "drawing out" nor still less a "pouring in" of knowledge. Dewey emphasises that the child is bursting with activity and what education must do is take hold of the child's activities and give them direction (ibid, p.36). In this context he condemns the classroom furniture and its arrangement as was common in his day in these words:

> ... the ordinary schoolroom with its rows of ugly desks placed in geometrical order, crowded together so that there shall be as little moving room as possible, desks almost all of the same size with just space enough to hold books, pencils and paper, and add a table, some chairs, the bare walls and possibly a few pictures, we can reconstruct the only educational activity that can possibly go on in such a place. It is all made "for listening" - because simply studying lessons out of a book is only another kind of listening; it marks the dependency of one mind upon another (ibid, p.32).

This description could be applied to any of the schools visited as part of the present research and it will be developed further in chapter 8. The phrase "dependency of one mind upon another" might equally well be applied to the Bantu education system which prevailed in black schools in South Africa until recently and which has left its mark on all those who suffered under it and

this includes most of the present generation of black teachers. The challenge to move away from that system is tremendous and the difficulties enormous. A first step forward must be an accurate description of what the present school situation really is and hence much of the present research must be descriptive.

3.2.3. Piaget

As a young man Piaget studied philosophy at the Sorbonne and he worked with Dr. Theophile Simon at the Binet Laboratory in Paris where he was occupied with the task of developing a standardised French version of Simon - Binet I.Q. tests. While engaged in this work he realised the wrong answers given by children revealed a pattern that was related to age and he soon rejected a quantitative definition of intelligence, which was the basis of the I.Q. tests, for a qualitative one - children of different ages use different methods of thinking (Ginsburg and Opper 1969, p.3).

So from the very start Piaget was concerned with the success and failure of children in tests, his theory and especially his method of research have had a great influence on educational research down to the present time as can be seen from most reviews of literature, particularly in the fields of mathematics and science e.g. Dickson et al (1984) in Children Learning Mathematics : A teachers guide to Recent Research devote sections in

each of the chapters on Spatial Thinking, Measurement, and Number to Piaget's work. In order to understand much of the school based research into success and failure in mathematics it is therefore necessary to present here a short review of his work.

Although Dewey and Piaget do not belong in the same "schools of thought" it has been pointed out that in some ways Dewey's work can be viewed as preparing educators for the acceptance of Piaget. Dewey stressed the importance of learning by doing in order to achieve true understanding as explained by Fischer (1964) and Piaget too stresses activity on the part of the child (Ginsburg and Opper 1969, p.177). Dewey's analysis of thought processes however was confined to abstract thought and working with abstract hypotheses (Dewey 1910, Chapter 6) but it was Piaget who showed that children think in different manner from adults and the level of abstract thought is only reached by some in adolescence. Both Dewey and Piaget stressed democracy in the school (Ginsburg and Opper 1969, p.231).

Piaget's early interest was in Biology and he did his undergraduate studies at Neuchatel in the natural sciences. He uses biological terms to describe learning for example "assimilation" and "accommodation" are functional invariants which enable the child to acquire new knowledge. Further he describes intelligence in terms of growth, stages, adaptation and equilibrium. Learning

in the widest sense (not simply superficial acquisition of specific responses to particular situations) depends on development - it can occur only when the child has available the cognitive structures necessary for assimilating new information. This development takes place in certain well defined stages which are described by Piaget in books published in the years 1936 to 1943: The origins of Intelligence in the child(1936), Construction of Reality in the Child (1936), The Development of Physical Quantities in the Child (1941) and others dealing with "number" and "perception". (For a description of the development stages see Ginsburg and Opper 1969, Chapter 3 to 5). The stages are: Sensorimotor, Preoperational, Concrete operational, Formal operational. Piaget's claim that all children pass through these stages in the same sequence is upheld in most research reports from experiments in Britain and the United States.

In the third world countries Orbell (1973) among others reports that resulting from his own research in Rhodesia it can be said the age at which equilibrium is attained for any given stage varies subject to cultural background and not all reach the highest stage of formal abstraction (Orbell et al 1973, p.11).

In a number of experiments using Piaget's conservation tests it was found that children in the Bafokeng region showed a time lag of 2 to 3 years when compared to white

South African children. These experiments were carried out by post-graduate workers in Phokeng under the supervision of the present researcher in 1988. This finding is similar to that reported by Van den Berg (1978) for other parts of South Africa.

Each stage is characterised by particular types of cognitive functioning and children at each stage think in a qualitatively different manner from children at another stage and of course from adults (as Siann and Ugwuegbu 1980, p.41 point out). These authors note the important fact - important especially for research in the African context - that each stage builds up in a progressive way on preceeding stages (ibid p.43). The importance of this notion for the present research into the success and failure in mathematics among the Tswana is obvious. If the earlier stages in cognitive development have not been successfully completed then later, more abstract thinking will not be achieved - indeed logically from Piaget's standpoint, the stage of formal operations will not be attained. Bramhare (1977) quotes Orbell (1970) who found among a group of African students averaging 13,6 years a near total lack of formal operational thinking. In a follow up study with 170 form IV students he found that only 42% of the male and 24% of the female students reasoned at the formal operational level in the Piagetian tasks. Biesheuvel (1957) obtained similar findings with South African subjects. Both Or-

bell and Biesheuvel attribute this relatively inferior mental functioning to the inhibiting effects of cultural impoverishment (Bramhare 1977, p.13). The same conclusions were arrived at during a workshop consisting of Professors J. Bruner, Doris Lee, John Lewis, Cyril Rogers and Dr. R.H. Stone which explored the relations between the learning process, traditional views held in non-technological societies and the development of teaching science and maths. It was accepted by the team members that experience at a very early age can be very important in developing in the child capabilities for abstract thinking. Certain play available to European and American children develops problem solving capacity and lack of such play - as in most African countries - leads to rote learning and dependence on memorisation (Lewis 1967, p.1). Growth during the first few years of life involves the mastery of certain basic skills which are themselves the tools for achieving higher order skills, in perception, language, competence in planning and attitudes towards knowledge. In most non-technological societies the culture is antithetical to maths and science because it stresses authority, rote learning, acceptance of the status quo and non-rational and non-mathematical explanations of phenomena (ibid p.2). The work of Gay and Cole (1967) and Cole et al (1971) in Liberia and of Bishop (1978) in Papua New Guinea raises serious issues concerning the cultural

differences. They showed that their third world subjects performed as well as, and in some tasks better than American and European counterparts when the task itself was meaningful, like estimating quantities of rice in a bowl. Bramhare (1977) poses this question: Could there be differences in cognitive preferences or perceptual orientations between the African and Western subjects that may make comparisons unwarranted? (ibid, p.13). Writing about the problem of poor mathematics performance of black South Africans, Van den Berg (1978) rejects Piaget-type studies as a possible research instrument. He quotes findings by Poole (1968), Beard (1968) and Vernon (1969) from different parts of Africa which show that black children lag behind English children by about two years as judged from their performance scores in Piagetian tasks. H.J. Dryer (1973) confirmed this by showing that 6 year old European scores are equivalent to 8 year old blacks in the R.S.A.. Van den Berg then sounds a word of caution:

> ... each group develops a hierarchy of values and norms within its own cultural heritage with the result that individuals can only be really understood within their own cultural content (Van den Berg 1978, p.49).

Okonji on the other hand combined Piagetian theory of cognitive development with his own differentiation theory to study cultural variables in cognition: Classification behaviour (1968), Understanding of Geometry (1971), Auditory and Visual Integration (1975). He

sought to identify what may be special to the cognitive operations of African children and eventually useful in maximising their learning (Lloyd and Gay 1981). This search led Okonji into Witkin's field dependence/independence theory (Okonji 1971) and will be dealt with later.

There have been serious criticisms of Piaget's stages of cognitive development, many of them arising from studies in third world countries. Price-Williams and co-workers (1969) matched two groups of children in Mexico - the one group from potter's homes, the other from homes of other occupational background and they found the children from the potter's homes were better at conservation of substance tasks. Beard (1968) in Ghana and Heron and Simonsson (1969) in Zambia found the degree of urbanisation and interaction with technology improved the % of conservers on Piagetian tasks. Lloyd (1971) showed socio-economic factors had an effect by demonstrating a significant correlation between conservation and degree of elitism of the family - Yoruba families in Nigeria.

Siann and Ugwuegbu say that Piaget's work is ethnocentric and is deeply influenced by cultural values (1980, P.61). Serpell (1976) supports this position and by reference to Dansen's review of the studies from many African countries suggest that even Piaget's method of data gathering by means of the clinical interview may be

so out of touch with the culture as to make the data unreliable, especially if the interviewer is a white person (P.72). Siann and Ugwuegbe quote other research which run counter to Piaget's stages: Bryant (1974) showed children aged 4 could .e logical inferences but this is only supposed to be possible after age 6 or 7; again Siegel et al (1966) showed children who were unable to conserve volume at age 5 could be taught to do so and hence they question the irreversibility requirement needed before children can conserve. Donaldson (1978) showed that changes in the experimental conditions can give contrary results and so with a variation of the three-mountain task she found children were not necessarily egocentric in the sense of being unable to picture another point of view (Pp 17-31). She points out that if the task is altered to make it more meaningful for young children then even children under the age of six can demonstrate the ability to d--centre. She refers to a task devised by Hughes (1975) which made use of policeman dolls and a boy doll. The task involved the coordination of two different points of view and the results showed that, contrary to Piaget's findings, children as young as three and four years could succeed in up to 90% of the trials. Donaldson says the two sets of findings can only be reconciled if we accept that in the Piaget three-mountain task the children did not understand what they were supposed to do. On the other

hand in the Hughes' test the situation makes sense to the child. The motives and the intentions of the characters are entirely comprehensible because for him the situation makes human sense i.e. it corresponds to basic human purposes and interactions (ibid P.24). With reference to Donaldson's work, Dickson et al (1984) say the results could be important when considering culture bias in the tests and this bias will be greatly aggravated by language and familiarity with technology (P.13). An example of such culture bias can be seen in an experiment carried out with 20 Bafokeng matric students of average age 19,4 years. Instead of the three mountains, models of a church, a box of biscuits, and a tin of vim were used. The testees were seated at a table looking at the three objects and then were shown a cut out doll which was placed at a different position. They were asked to identify which of 7 cards each showing a drawing of the three objects as seen from different positions, was the one that the doll could see. Only six of the twenty tested were able to select the correct card. Most of the others simply chose the card showing their own viewpoint or made what seemed wild guesses. When asked to explain it became clear they had not understood the instructions in the same sense as the tester and they were adding a whole human dimension to the task which the tester had not thought of e.g." This small boy (the cut out doll) doesn't know anything about

the church and he has no use for the vim. He only sees the biscuits."

Among the criticisms of Piaget are that his tasks are culturally biased in the use of materials and further that there is a language problem which often prevents tester and testee from understanding each other as shown in the above example. These are important issues for the present research and both are dealt with again in chapter 7. It must also be remarked that there is a distinct possibility that school mathematics is culturally biased against African students in the materials, examples and excercises used and also in its use of language. Language is discussed in chapter 7.

More fundamental criticism is that of Groen and Kieran (1983) who say that Piaget's theory provides no apparatus for bridging the gap between his empirical work and school mathematics (p.353). These same authors claim that in his later writings Piaget dispenses with the need for stages at all (p.366). It is certainly true that in his later years he was more and more concerned with genetic epistemology which has as its fundamental hypotheses that there is a parallelism between the progress made in the logical and rational organisation of knowledge and the corresponding formative psychological processes. He believed that it is with children that we have the best chance of studying the development of logical knowledge, mathematical knowledge

etc. (p.360).

The importance of Piaget can be judged from the amount of research he has sparked off and even from the extent of criticisms levelled against his theories. Be that as it may the present research into mathematics among the Tswana has been greatly influenced by his work on number. Piaget (1952) suggests that in order to handle natural numbers flexibly in solving problems children need: (i)Conservation by which a child can recognise a one to one correspondence still exists between two sets even when one is spread out more; (ii)Seriation or ordering which is the ability to arrange sticks, dolls etc. in order of increasing size and to know where is the 7th, 8th etc.; (iii)Class inclusion which is the simultaneous recognition of a total class and one of its subclasses e.g. 5 objects can be 1, 2, 3, 4, 5, in its own set and when added on to a set of four objects this old set of 5 will now be 5, 6, 7, 8, 9. Piaget thinks these three operations are simultaneously achieved at about age 8 (Dickson et al 1984, p.198).

Piaget's method of clinical interview in order to find out how the child is thinking is still seen as the best technique available in spite of the warnings of Donaldson and others referred to above. It is especially important for the present research to pursue an in-depth study of individuals rather than a large scale more superficial survey of the population to study the

research question. Indications are that African subjects achieve mastery of Piaget's developmental stages later chronologically, than their European counterparts; yet all follow the same school syllabus. It is possible in this case that African subjects are studying material in mathematics which is not matched to their stage of cognitive maturation. This has been noted by Macnab and Cummine (1986): one major source of learning difficulties is the conflict caused in children whose thinking is still at the concrete operational stage but who are required to cope with formal operations' (p.23). It was important for this research to record instances of "delayed mental development" which might be related to failure in mathematics. Similarly it was important to record indications of ability to hypothesise and deal with formal operations which might be related to success in mathematics. Lastly Piaget claims reversability is fundamental to the child's mastery of the arithmetic operations of addition, subtraction, multiplication and division. The present research explored how students perform in picture problems involving these operations. It took note not only of the strategy used but also how the students check their answers to establish if the students view addition/subtraction and multiplication/division as connected.

3.2.4. Skemp

Some authors do not fit easily into prearranged patterns and this is true with regards Skemp and the framework of this chapter. Should he be included here among the psychologists or in the next section for his school based research in mathematics? Skemp was originally a school teacher and only turned to psychology in his efforts to understand how children learn (Skemp 1971, p.15). After taking a psychology degree in Oxford in 1955 he worked in the psychology department of Manchester University until 1972 where his special interest was in the psychology of mathematical education (ibid). During this time he directed the Leicestershire Psychology and Mathematics Project. In 1973 he became professor of education at Warwick and he developed his model of intelligence based on process rather than structure or development. Intelligence was considered from the point of view of dealing with the world in which we live and especially goal attainment. That which enabled a person to achieve his goal was what Skemp described as a director system. But Skemp was not caught up in cognitive theorising - on the contrary he realised that the whole person is involved in learning and emotions play an essential part in human experience (Skemp 1979 P.11). In regards to mathematics understanding Skemp faced the issue by posing the question: What happens when we understand that does not happen when we don't? (1971,

p.14). He defines understanding thus: To understand something means to assimilate it into an appropriate schema (ibid, p.46). It is not an all or nothing state. Better internal organisation of a schema may also improve understanding and clearly there is no stage at which this process is complete. To return to Skemp's original question we find that some ten years after he wrote the above definition he now rephrased the question and in 1980 he asked: What can we do when we understand that we can't do when we don't understand? (1980,p.2). He answers this new question by showing that when there is understanding then we can do three things better: (i) achieve our goals; (ii) co-operate with our fellow beings; (iii) create (ibid).

In the analysis of understanding Skemp defines two modes namely "relational" and "instrumental" (Skemp 1976). By the former is meant what most people mean when they use the verb "to understand" i.e. they know both what to do and why they are doing it. Instrumental understanding on the other hand is described as "rules without reasons". Other writers have since added two other modes of understanding to include "formal" and "intuitive" understanding (Macnab and Cummine 1986, p.34). Skemp's discussion of understanding provides a framework for the present investigation into how the Tswanas understand mathematics. Very few students or even teachers seem to have a relational understanding of

mathematics and they cannot apply their mathematics in new situations or even in solving problems which are only slightly different from those already practised. It would seem the teaching is geared only for instrumental understanding just as Skemp says. Many teachers settle for the instrumental mode of understanding because it has the distinct advantage of getting the right answer quickly most of the time (Skemp 1980).

Skemp's main work has been concerned with the nature of intelligence and over the years he has developed a model of intelligence in terms of a goal oriented director system as will be explained just now. First some key ideas used by Skemp are described then a discussion of his model of intelligence and a critical comparison of his model with that of Piaget is given. The reason for this exploration is that it provided a starting point and guide line for carrying out the present research into success and failure in mathematics.

In the introduction to The Psychology of Learning Mathematics (1971), Skemp briefly reviews previous literature on the nature of intelligence. It is generally agreed that there are two kinds of intelligence:

(i) Intelligence-A, which is an innate capacity for development which, he says, amounts to the possession of a good brain and a good neural metabolism and

(ii) Intelligence-B, which describes the functioning of

the brain in which development has gone on (P.16). He quotes Vernon's (1969) definition of Intelligence-B:

> ... the cumulative total of the schemata or mental plans built up through the individual's interaction with his environment, in so far as his constitutional equipment allows (ibid)

Skemp goes on to say that Intelligence-B is largely undeveloped in many culture and the difference between the technologically most advanced cultures and the most primitive is not due to the differences in Intelligence-A but to differences in Intelligence-B, since it is this latter which is effective in controlling the enviroment (P.18). Such ideas must be studied against other authors such as Ginsburg (1982) who reported that:

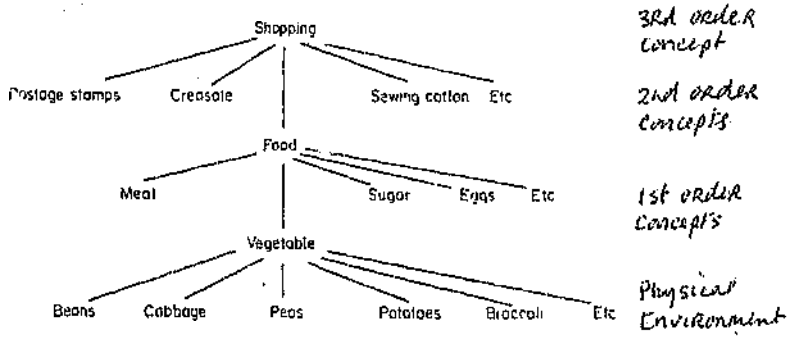
> ... unschooled Africans seem to organise school arithmetic in the same fashion as schooled Americans ... the dominant impression is one of common cognitive processes and robust development of systems of mathematical thought.

The ideas expressed here give rise to serious questions for Tswana students on the broad spectrum of cultural differences; however, what is of interest to the present researcher is the fact that some students - having the same cultural background as the others - still manage to perform so much better than their companions.

In a more recent work entitled Intelligence Learning and Action (1979), Skemp builds up a model of intelligence which he claims provides a core of a unified theory of education. He makes use of many of the ideas put forward in his 1971 book, especially the following:

(i) Concept which he says is a single abstraction. It may be first order if it is derived from sensory experience directly; or second order, if derived from other abstractions already made; or thi urth, etc, each being farther removed from initial re . sensory experience.

Fig. 3.1. Levels of abstraction



Skemp (1979, P.115).

Floyd (1981) quotes Skemp as laying down two principles for the learning of mathematical concepts:

> 1. higher order concept cannot be communicated by a definition, only by encountering a suitable collection of examples.
> 2. since in maths these examples are usually other concepts it must first be ensured that these are already formed in the learner i.e. the necessary lower order concept must be present before the next stage of abstraction is possible (P.83).

These principles have serious implications for the present research because much of the std 7 maths syllabus is "algebra" which can be thought of as generalised arithmetic. Have the std 7 students mastered the basic operation in arithmetic which is the

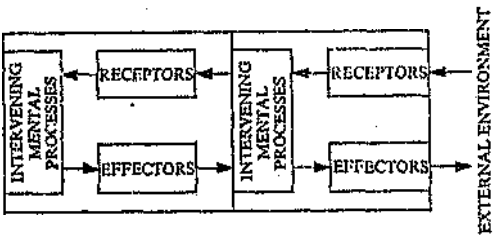
foundation for algebra?

(ii) Schema is the word he uses for the linking structures between concepts whose function it is to integrate existing knowledge and to provide a sort of mental tool for the acquisition of new knowlege.

Skemp (1979) gives the plural as "schemata" or "schemas". (p.219) Piaget uses the word "scheme" to signify "the structure or organisation of actions as they are transferred or generalised by repetition in similar or analogous circumstances."

(iii) Mental processes may be either intuitive or reflective i.e. knowing an answer as opposed to knowing how one arrived at the answer. Skemp suggests the following diagram for describing and analysing mental processes:

Fig 3.2. Relationship between intuitive and reflective mental processes



Skemp (1971, p.58).

(iv) Director system

In chapter 5, Skemp (1979) describes his model for in-

telligence in terms of a director system occupied with desired goal states. This system has four component parts as shown in fig 3.:

The components of the system are:

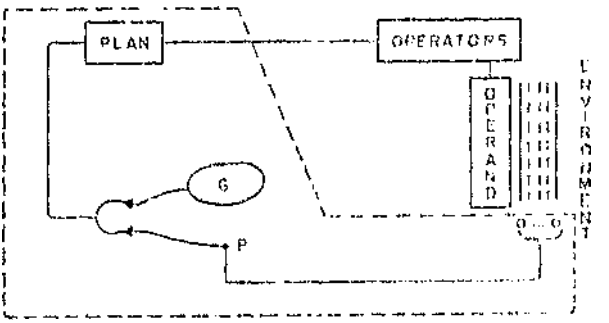
i) A sensor which is sensitive to the relevant aspect of the present state of the object. By state here he means the relationship between the operand and the environment.

ii) A part by which the goal state can be set.

iii) A comparator which represents the difference between the present state of the operand and its goal state.

iv) A plan which determines what happens when the object is not in its goal state (ibid p.49).

Fig 3.3. Components of a director system



The director system is enclosed inside the dotted line.

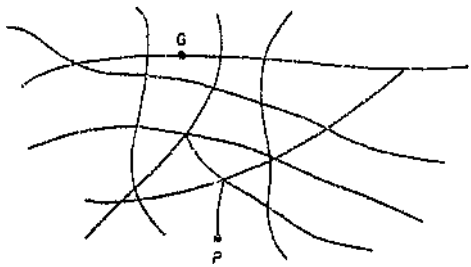
Skemp (1979, p.49).

The interaction of these components with each other and how the whole system relates to the environment is shown in Fig 3.3.

(v) Cognitive map

In chapter 11, Skemp (1979) uses the structure of a cognitive map to describe intelligence and understanding. The relationship between knowledge and action and the role of schemata he discusses as possible routes from the present position to a desired goal state as shown in fig 3.4. Each point represents a state of an unspecified kind; movement along a line represents change from one state to another and the lines and their connections show the possible ways of taking the operand from one state to another.

Fig 3.4. Diagram of intelligence as a cognitive map



P = present state; G = goal state.

Skemp (1979, p.145).

Skemp is concerned with what intelligence does i.e. its function, not what it is made of. He defines it as a

quality of these higher mental processes by means of which we become able to direct our activities towards goal states favourable to survival (ibid, p.51).

An example of how some of the above ideas might be used to help in the present research is given here as an illustration of how the work of Skemp guided the analysis of students' performance in mathematics. The student would be given a card with a drawing. The drawing would show a boy who tells his name and says he has four boxes of sweets just like the one shown. Beside the boy would be a drawing of a box with a certain number of sweets. Underneath the drawing would be the question: How many sweets does this boy have?

The present state is given in the form of a picture and words. The student must identify the given information. The goal state is given in the form of the question at the bottom of the card. The student would be required to devise a plan for solving this problem - in this case 4 x 8 = 32 sweets. Scores could be allotted to each step to enable comparison to be made between individuals. This discussion is taken up later in chapter 5 in the research design.

Skemp acknowledges his debt to Piaget's work but is careful to indicate how they differ, and three points of difference are relevant for the present research. These points are:

(i) Piaget uses the word "scheme" defined as "the

structure or organisation of actions as they are transferred or generalised by repetition in similar or analogous circumstances" (Piaget and Inhelder, 1969, p.4). By definition then Piaget closely links "scheme" with action. This contrasts with Skemp's notion of "schema" which he sees as a conceptual structure which exists in its own right independant of action (Skemp 1979, p.219).

(ii) Piaget's model of intelligence is based on equilibration: "intelligence constitutes the state of equilibrium towards which tend all the successive adaptations of a sensori-motor and cognitive nature, as well as all assimilatory and accommodatory interactions between the organism and the environment" (Piaget, 1950). This differs from Skemp's model of intelligence defined as a second order goal-directed activity.

(iii) Piaget conceives of intelligence as a stage of mental development, reached after a succession of earlier stages. Skemp, on the other hand, speaks of intelligence as that mental function which brings about changes from more concrete forms of thinking to higher levels of abstraction (Skemp 1979, p.220).

To better see how Skemp's work can be applied in practice there is given here a review of one experiment carried out in Singapore secondary schools on the teaching of mathematics. The conceptual basis for the ex-

periment was Skemp's(1976) work on instrumental and relational understanding. Chinese-medium and English-medium students, both boys and girls, were taught a topic in Trigonometry during a series of 10 lessons. Some Chinese-medium classes and some English-medium classes were the experimental group and they were taught by an experimental method including dicussion and activities both within and outside the classroom. The sequence was designed to maximise the possibility of securing relational understanding. The control classes were taught by their usual class teachers using the direct method and school text book as prescribed in the school syllabus on the assumption that this would promote an instrumental learning strategy. Statistical analysis of pre-test and post-test scores was carried out after the students had been matched with respect to sex, medium of instruction, age and mathematical attainment as shown in pre-test. In the conclusion Purbick et al(1982) report that the Chinese stream students who followed the experimental programme of lessons designed to secure relational understanding seemed to have enjoyed a significant benefit. On the other hand the English stream students' understanding was not significantly related to experimental or control type of teaching. To explain the result the authors note that Chinese-medium students are learning mathematics in English which is for them a second language and hence in

the experimental lessons they were less dependant on language and had in a sense experience with direct access to the mind, allowing the student to think in Chinese about what was going on. In the traditional method classes these students were dependent on the English language medium and the authors suggest this prevented them from building up concepts and reduced them to memorisation and instrumental learning.

The English medium students gained no particular advantage from either method because they were not disadvantaged by the use of English as the medium of instruction.

This experiment raises questions about the language medium in Bophuthatswana schools which are important for the present research. According to the findings reported by Purbrick et al students learning mathematics in a second language are severly handicapped by a teaching method which relies on language although the bad effects of this can be minimised by the use of lots of experimental apparatus and out-of-class demonstrations. In the experience of the present researcher the common, and often only, method used in the Bafokeng region schools is the "chalk and talk" method. There is an almost total lack of teaching aids, apparatus of any sort is lacking and no stimulating materials can be seen in any of the classrooms. This investigation included visits to the schools and observation of mathematics

lessons taking into consideration the points made here and reported in Chapter 8.

One last topic discussed by Skemp and found to be applicable to the present research is the manner of reality testing (1979, P.28). What is involved here is how we know we have arrived at a solution and how do we know it is right. Traditionally with the Bafokeng a child would never dream of questioning his elders. Teachers are seen to be elders and when they present a solution to a problem in mathematics there is no precedent in the culture that would encourage a child to verify this solution for himself. Right and wrong are decided by his elders. However it is essential for a relational type of understanding in mathematics that the student does check the answer. It was also investigated in Chapter 6 if successful maths students are the ones who have an awareness of the importance of checking which the students weak at maths don't have.

3.2.5. Witkin

In the experience of the researcher mathematics is taught in the Bafokeng schools generally using an analytical approach and students must be able to restructure the parts in order to find a solution. Success in mathematics then would depend on this analytic/restructuring ability. Witkin and his associates have developed a theory of personality and cog-

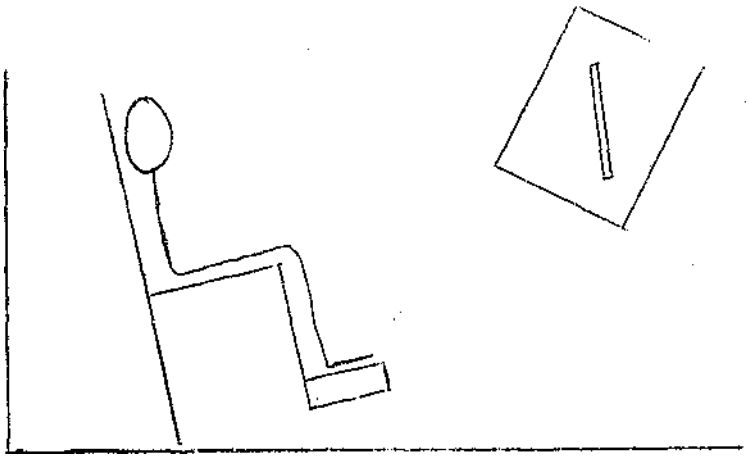
nitive style which is correlated to perception and degree of differentiation of the self from the non-self. Witkin's work was done in America but it has been replicated by Dawson, Okonji and others in Africa. According to Siann and Ugwuebu in terms of amount of research in non-Western countries Witkin, comes second only to Piaget (Siann & Ugwuebu 1980, p.211). The original work was carried out in the forties in laboratory studies of perception of the upright. It was discovered that people were quite different from each other in their performance but they were self-consistent in the manner of establishing the upright across tasks - this was seen to be a question of perception. Some people relied on the visual and were unable to adjust a rod in a tilted frame so that the rod was vertical; others relied more on their body sensations and they could adjust the rod into a vertical position even when the frame was tilted (Witkin & Goodenough 1981, p.7). Witkin decided to use the terms field dependent for the former group and field independent for the latter (ibid, p.13).

In the research on field dependence and field independence the two tests which were most frequently used were the Rod-and-Frame Test (RFT) and the Embedded-Figures-Test (EFT). The former test requires an elaborate mechanical and structural set up but the latter is a straightforward paper and pencil test.

The Rod and Frame Test (RFT) is carried out in a small

darkened room in which the subject is seated facing a luminous rectangular frame having a luminous rod mounted centrally within it as shown in fig 3.5.

Fig 3.5. Experimental arrangement for the RFT



(Jordaan et al 1975, P.404)

The chair, the frame and the rod may all be tilted independently and the subject is asked to place the rod in the true vertical position. Those who can adjust the rod to a vertical position are said to be field independent, those who cannot are field dependent (Witkin et al 1954). In this test the subject had to extract an "item" from the field in which it appears. Success in this test indicates analytical and articulated perceptual style because the person is able to differentiate the elements from the total perceptual

field and then integrate them again (Riley et al 1959, p.67). There was great interest in this area and many studies published in the fifties have dealt with field dependence/independence: Linton (1955), Rosner (1957), Block (1957), Gross (1959), Jackson (1957) etc as pointed out by Riley et al (1959, p.68). Most of these were correlation studies.

Through conversations with the subjects Witkin began to realise that personality was related to the manner of perceiving the upright in space and after using embedded figures tests it became clear that performance in these latter tests was also related to perception of the upright. Witkin reported these findings in a book published in 1954 entitled Personality through Perception described by Goodenough (1986) as a landmark volume.

The personality types were deemed to be horizontally bipolar and value neutral i.e. the two types were considered to be mutually exclusive at opposite ends of a continuum but neither type was regarded as superior or inferior to the other. Most people were regarded as situated somewhere along the continuum between the two poles. In general terms a predominantly field dependent person:

(a) tends to judge the world in a rigid fashion according to his established frames of reference;

(b) does not easily change his set ideas concerning people, things or situations;

(c) is easily bogged down by details because of his inability to coordinate these details and perceive a new totality.

On the other hand a field independent person:

(a) has a more flexible outlook on life;

(b) is less inclined to perceive in extremes (e.g. right/wrong, very good/bad);

(c) is able to recognise the elements in a perceptual situation (analysis) and coordinate them into a new and meaningful whole (synthesis) (Jordaan et al 1975, p.172).

A number of writers have criticised Witkin's personality types as being "centri-cultural" i.e. having unattractively ethnocentric overtones e.g. Wober (1969) and Serpell (1976) as pointed out by Siann & Ugwuebu (1980, p.213).

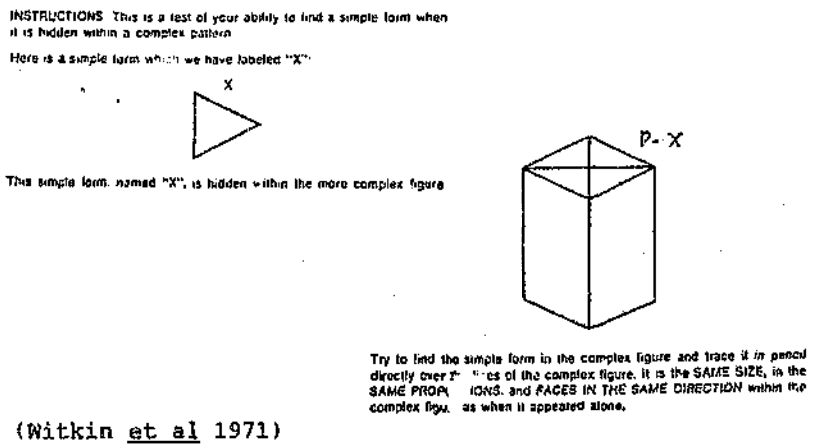
In his second landmark book Psychological Differentiation published in 1962 Witkin subsumed field independence as a very specific construct at the base of a pyramid with the differentiation construct at the apex (Goodenough 1986, p.8). Differentiation implies segregation, of self from non-self, of psychological activities (e.g. thinking from acting), also hierarchical structure of functions and specialisation of function at the neurophysiological level. The last mentioned refers to lateralisation whereby the two cerebral hemispheres specialize in functions (Witkin & Goodenough 1981,

p.19). Cerebral dominance and perception is an area in which there is a considerable amount of recent and current research but it will not be reviewed here. [See Jordaan & Jordaan (1975) for a simple explanation of the ideas put forward by Sperry (1968 and 1970) in this context: a normal right handed person tends to have a dominant left hemisphere housing the mechanisms which enable him to express himself by the spoken and written word, to organise coherently the language he speaks and to understand its meaning; whereas the right hemisphere is subordinate in its function of spatial construction and non-verbal ideation (op cit, p.168). Pizzamiglio and Zoccolotti discuss how cerebral structure and cognitive characteristics are related to individual differences of field dependence/independence (Bertini et al 1986, chapter 4).]

Witkin and his co-workers also developed an embedded figures test (EFT) in an effort to find a simpler task than the rod and frame test (RFT) whereby an investigator could assign a given subject to one or other category of field dependence/independence. The EFT is quite different from the RFT in the sense that it is a paper and pencil test. The subject is required to isolate a given simple figure P from a more complex one P-X as shown in Fig 3.6. Variations include the use of colour or shading. Further developments include a children's embedded figures test and a group test (GEFT)

(Witkin et al 1971). More detailed explanations of the GEFT are given later in chapter 9, section 9.4.3.

Fig 3.6. Sample item from EFT



(Witkin et al 1971)

Very high correlations were obtained between scores on the embedded figures tests and the rod and frame tests in America so that it became popular to use the EFT as a measure of field dependence/independence. Wober found this was not the case in African subjects with whom he used both RFT and EFT (1966 and 1967). He found that his Nigerian subjects showed closer similarity to American professional dancers than to other American subjects in that both groups showed no significant correlation between RFT and EFT scores. He also found that formal (Western) education had more bearing on EFT than RFT results. Wober (1967) concluded that RFT contains a proprioceptive component making it essentially different

from tests like EFT which involves purely visually mediated transactions. (Wober 1967,P.37). It seems then that the criticisms listed by Siann & Ugwuebu (1980,P.213) are relevant when we attempt to use Witkin's ideas in a cross-cultural context. It may very well be true for American field dependent individuals that they are dependent:

(a) socially i.e. conform easily, unsure of themselves, submit to authority, rely in their perception of people, things and situations, on the opinion and attitudes of others especially authority figures, easily change their stated views on social issues under the direction of authority;

(b) emotionally i.e. their perceptions and thoughts are strongly influenced by their own emotional dispositions, have difficulty in isolating subjective personal feelings in order to reach an objective judgement;

(c) cognitively i.e. use the defence mechanisms of repression and denial when faced with threatening stimulus situations, hence their memory of what they perceived, said and did or thought is blotted out and often they change their own views in accordance with current popular opinion (Jordaan et al 1975, P.407). However none of these characteristics may apply in another culture (Wober 1966, P.184).

Witkin's work led to the development of a study of cognitive style and its application for the analysis of

successful classroom teaching. In a class situation there will be serious learning disabilities for students if their learning style is not matched with the teaching style adopted by the teacher. The possible preferred learning style of std 7 students in the Bafokeng region must therefore be investigated especially with reference to perception.

It was not foreseen that all aspects of cognition would be dealt with in the present research due to constraints of time and resources and perception has been selected for a more thorough investigation. The literature suggests successful maths students tend to be more field independent. The embedded figures test can be used in the present research to explore the relationship between mathematics achievement and scores in embedded figures tests obtained by std 7 students in Phokeng.

In discussing the origins of individual differences Wikin et al (1971, P.11) indicate that research shows a relation between the extent of a child's field dependence and the degree to which his early socialization experience hampered or fostered achievement of separate autonomous functioning (ibid P.12).

Other research reviewed by Pizzamiglio & Zoccolotti (1986) explores the theory of genetic control (Bé ini et al 1986,P.33). The truth is that both of these interact in any given individual most likely. The environmental variables are listed as :

(i) training, (ii) child-rearing practices, (iii) culture and (iv) eco-cultural factors. The evidence suggests that spatial visualization, disembedding and perception of the upright may be affected by a variety of educational programmes (Brinkman 1966),(Wober 1967),(Bishop 1983).

Child-rearing practices that encourage continued reliance on parents inhibit development of field independence (Witkin & Goodenough 1981,P.81). Dawson (1967) and Okonji (1969) found that field dependence was associated with polygamy which may promote the type of infantilizing and over-mothering socialization that lead to the development of field-dependence (Okonji 1969,P.304). By culture in the context of this discussion is meant social setting, and Witkin & Berry (1975) identified two groups with different social arrangements and standards. One group stresses conformity and has elaborate social structure and insists on strong parental authority within the family and this group was found to be more field dependent; the other group has more looseness, autonomy and in contrast to the first group where the father plays little or no part in the child's upbringing the second group have both father and mother participating in emotional and physical care of the child, this group is more field dependent (Witkin & Goodenough 1981,P.89). Finally ecological factors also contribute to field dependence/independence as shown by

Berry (1966), who compared a group of Eskimo subjects with a group of West African ones, also Dawson (1967) who did comparisons in Sierra Leone, and Okonji (1969) who compared the effects of rural and urban environments on the development of cognitive styles among children (Okonji 1969,P.295).

All this seems very far removed from success and failure in mathematics but it may not be the case if we consider the following: a person who is field dependent has a cognitive style which is global in perception, which organizes and labels stimulus configurations in a certain manner without being able to disembed them from the surroundings and now this person is faced with a learning situation which emphasises analysis and synthesis and which rates performance and even intelligence on achievement in tests based generally on an analytic style of thought (Gonzales & Roll 1985,P.193). And in fact even a cursory glance at the Western type schools in Africa shows they are indeed Western - in organisation, administration, control, syllabus, teaching methods and so on, and they are geared to produce field independent persons. Wober (1966) attempted to identify "sensotypes" as an alternative to Witkin's field dependent class. By this he means the pattern of relative importance of the different senses, by which a child learns to perceive the world and in which pattern he develops his abilities (Wober 1966, P.182). Wober

remarks:

> Visual material is the currency of communication in an American, western society where the tests (RFT and EFT) were developed. But the visual world and transactions therein may not be so relatively important in an African culture ... and the language may not hav the availability of words and hence ideas as an apparatus necessary to the elaboration of an analytic style in the visual field in which his tests lay (P.181).

By contrast with the Western "visual" Wober describes cultures that have tonal languages, (not to mention clicks as in South African black languages) and rich experience and discernment of rhythm and physical movement in dancing. Hence Wober says children in such cultures are skilled in different media from the Weste n visual medium, they are more proprioceptive and auditory than visual (ibid P.188). Thus when we consider the failure of our Tswana children in mathematics perhaps we need to look at different teaching approaches and learning techniques - group interaction and shared responsibility between teacher and pupil as opposed to the lecture and discovery method presently in favour, maybe there we can find the beginning of a solution to the problem. Hence the question: Do the Tswana students have preferred modes of thinking? Can these be identified and described?

It may be that Tswana students learn better from an oral presentation than from written material. Perhaps they need time to discuss new material in smal groups or even in whole-class groups in order to assimilate it.

No research has been found which examines these possibilities.

3.3. School based research into mathematics

The concept "mathematics" was dealt with in Chapter 2 and an operational definition for the purposes of this research was given in terms of (a) knowledge and (b) skills. In the past there has been much criticism of that kind of school mathematics which concentrated on drills and computational procedures. The aim of high level of skill in number manipulations was manifested and measured in speed and accuracy. The newer approach to school mathematics has tended to downplay the skill aspect in favour of a deeper level of understanding. Riley et al (1983) have reported on investigations into the relationship between conceptual knowledge and procedures in mathematics. They conclude:

> ... that children's procedural knowledge leads to the acquisition of schemata and these schemata in turn are involved as intermediate steps in acquiring more advanced procedures. More work is required to explicate further the nature of this interaction (Ginsburg 1983, P.191).

Children who fail in mathematics then may be lacking in either (or both) of these: knowledge or skill. Therefore these topics will be the focus of this section of the literature survey. But this field is still too broad and it was decided to be guided by two works on mathematics teaching and learning in England covering

the age group 11 to 16, which corresponds more or less with our middle school range in Bophuthatswana. These works are:

Children's Understanding of Mathematics 11 - 16 (Hart ed. 1981) and Mathematics 11 - 16: A Report prepared for the Mathematical Association (1974).

3.3.1. Mathematics research in England

"Children's Understanding of Mathematics 11 - 16" (Hart ed. 1981) is the report of a team of workers in the programme entitled Concepts in Secondary Mathematics and Sciences (CSMS) and edited by K.M. Hart. The research was done from 1974 - 1979 and it was based in schools and on the school curriculum. The aim was to develop a hierarchy of understanding in mathematics, called a "Concept Tree", which would provide information for teachers and other developers of curricula in England. Eleven different topics were selected to find the types of questions children can answer easily and which type they find difficult. The topics were: measurement, number operations, decimals, fractions, positive and negative numbers, ratio, algebra, graphs, reflections, vectors. Written tests were devised on these topics and presented in problem-solving format in order to probe understanding - not merely to test skills. These tests were followed up by interviewing children for the purpose of:

(a) Clearing up misunderstandings in wording of questions and
(b) finding out methods used and the errors made by children when doing maths problems.

Each interview lasted about one hour and the child was asked to talk his way through the problems explaining what he was doing. Some of the difficulties associated with the interview method are referred to. The replies as to why the child used a particular method were ...

> often tautologous, the child essentially saying it is so because it is so. Sometimes the replies were no more than an expression of feeling ... (P.215).

A lot of use was made of Piaget-style questions adapted by CSMS and a number of correlations made with Piaget's stages of development. The most noticeable differences between the two would seem to be:

(a) Piaget's focus was on the child; CSMS focussed on the child doing maths
(b) Piaget used material, concrete objects; CSMS relied on paper and pencil tests and written symbols.

No model of intelligence is presented. There is a model of mathematics as a body of knowledge which can be arranged in a hierarchy of concepts of increasing difficulty; there are also presented various strategies used by children in solving problems. A parallel may be seen in Piaget's schemata and Skemp's goal-orientated activities which enable a child to move from a given present state to a desired goal state.

The whole research highlights differences between students who are good at maths and students who are not

good at maths. At a given age a bright child has mastered topics which are higher in the concept hierarchy than his peers. This seems to be a mere statement of fact without an attempt to analyse the reasons why this should be so or to identify factors associated with good maths performance.

The authors of the 1974 report for the Mathematical Association claim the core of mathematics is pattern: patterns in number, in space, in algebraic form, in symbolism, in thinking. Within the general theme of pattern they say number is the mathematical model of greatest use in everyday life, (P.5).

> Number properties are easy to understand when correctly presented, and yet they are the basis of the most powerful methods of abstract mathematics. It is important that children should know what are the significant properties of numbers and the operations on them, and also that they should understand the common conventions used in the written expression of numbers and of statements about them (ibid P.6).

Following from the work of the developmental psychologists like Piaget and that of process psychologists like Skemp it is clear that whatever view is taken of cognition the early work on lower order concepts must be well done. If children fail to make the grade in middle school mathematics it is likely the problem lies in the fact that they did not succeed in building up a sound base in their earlier years. The concepts either were not formed properly or the children were forced into using algorithms at too early a stage

and the only way they could cope with the school demands was by rote memorisation. Hence it has been decided that out of the vast amount of literature on school based research into mathematics that has been published over the last twenty or so years only that concerned with number and the four basic arithmetic operations of addition, subtraction, multiplication and division will be reviewed. It is believed by this researcher that in failure to achieve mastery in these areas lies the answer to the question of why some students succeed in mathematics and others fail. All this must of course be moderated in the third world countries by cultural factors and theories of cognitive style as proposed by Witkin. Perceptual modes as explored by Okonji, Deregowski and Wober as mentioned earlier in section 3.2.5. could play an important role in helping to identify the difficulty which seems to be peculiar to the acquisition of adequate mathematics concepts in the African context. There follows below a review of research on number, basic operations, strategies and problem solving.

3.3.2. Number

As the 1974 report prepared for the Mathematical Association says:

> Our first acquaintance with numbers is with the natural numbers (1,2,3 ...) which are used in counting. We often take them for granted and do not think about them very much ... Mathematics 11 - 16.

Fuson and Hall (1983) have reviewed the literature extensively and they have come up with a wide variety of meanings and uses of number words as follows:

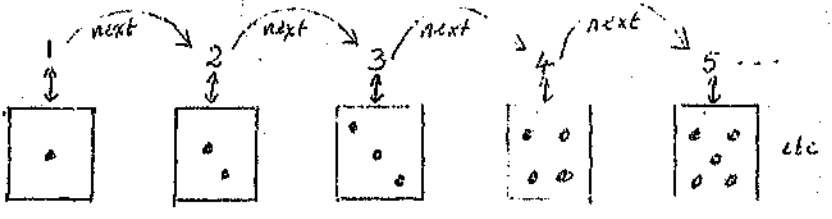
(i) Knowledge of conventional sequence of the words. The mere learning of words in correct sequence is a considerable task and may so preoccupy the young child that he is unable to attend to anything else. An example of the difficulty is the way children struggle to learn "runs of numbers" like 1,2,3,4,5.....8,9,10.... etc as reported by Gelman and Gallistel (1978 P.93). Fuson and Hall (1983) remark on the socio-economic effect on learning number sequences. They refer to a study by Ginsburg and Russell (1981) who reported S.E.S. effects on mean lengths of accurate number word sequences for samples of middle-class and poor inner-city 4 year olds to be 20 and 15.5 respectively. Similar results were obtained by Hughes (1981) in a study of middle-class and working-class children aged 3 - 5 years in Edinburgh (Dickson et al 1984, P.191).

(ii) Use of words in counting. The act of counting is quite involved because the child must apply a one-to-one principle according to Fuson and Hall (1983, P.57) and it is usually accompanied by pointing or some other body movement by children up to the age of five. Greeno, Riley and Gelman (1978) have developed a model of

children's counting which they describe as a "mental number line". The model consists of an ordered list of numberlogs linked by a successor relationship namely "next".

Diagramatically it looks like this in figure 3.7.

Figure 3.7. Diagram of "mental number line"



Resnick (1963, P.110).

The quantity of a set is established by a procedure that uniquely links each object in the set with one of the number logs and then designates the last number log named as the number of the set.

It is not clear whether Greeno and associates who present the mental number line above are conceptualizing from the researcher's point of view or that of the child. If it is the latter who are considered to have a mental number line image then it ought to be relatively easy for them to count in skips like: 2,4,6 ... or 3,6,9 ... etc. But this is not consistent with findings of Behr et al (1983) or Novillis-Larson (1980). In research to explore rational number concepts of 4th graders in American students Behr et al report a dis-

proptionate number of errors in number line problems and their results indicate that number line interpretations are especially difficult for children (P.113). Novillis-Larson presented 7th grade students with tasks involving number lines and fractions. Where the line was divided into divisions of "2" instead of "1" students failed to recognise this from the labelled numbers and persisted in counting in ones. When a number line of length two units was used approximately 25% of the sample used the whole line as the unit (Behr et al 1983, P.94).

(iii) Corresponding numerical symbols. Fuson and Hall (1983) report that little evidence exists concerning children's knowledge of the one-one principle i.e. that each item in an array must receive one and only one counting word (P.57). It seems likely that mastery of this one-one principle and the abstraction of "oneness" "twoness" etc. with the use of the corresponding number symbols go hand in hand with the child's development of number concepts.

(iv) The cardinal meaning is to describe the numerosity of a set - how many elements? Fuson and Hall suggest that in the early years a child can only use numbers in a physical context (e.g. 2 chairs, 2 sweets etc.) and only later form a more general concept of twoness - not known at what age nor in what way this abstraction occurs (Fuson and Hall 1983, p.59). Certain African lan-

guages have been shown not to have separate words for "two", "three" etc. and are limited to speaking about "two men", "three dogs" etc. (Gay and Cole 1967, p.52). A crucial step in applying the counting procedure in a cardinal context, claim Fuson and Hall is :

> ... learning that the last number word said gives the numerosity of the set (1983, p.65).

This is called the cardinality rule by Schaeffer et al (1974). It means that when a child in counting objects says: one, two, three ... nine, ten ... he must shift into the cardinal use of ten away from the ordinal ten so as to name the group as consisting of ten objects.

(iv) Measure meaning. The measure use of number is best illustrated in the use of scales i.e. units marked with numbers. Fuson and Hall (1983, p.80) suggest this use of number has important applications in every day living (e.g. rulers, thermometers, weighing scales etc.). The 1977-78 National Assessment of Educational progress in mathematics found that in the United States 70% of the 9 year olds and 40% of the 13 year olds made errors in measuring simple line segments with a ruler (Fuson and Hall 1983, p.81). This correlates with the number line difficulties reported by Novillis-Larson (1980) and Behr et al (1983) above. Hart (1981) reports on findings with children in the 11 to 16 age group on measurement in which the focus was on conservation. Hart (1981, p.22) says the essential aspect of measur-

ment includes the fact that length, area and volume of objects are not changed by displacements - but approximately 30% of secondary school students are not sure of this. Hart gives this example: subjects were given the diagram as shown in fig. 3.8. and then asked to choose one of the following:

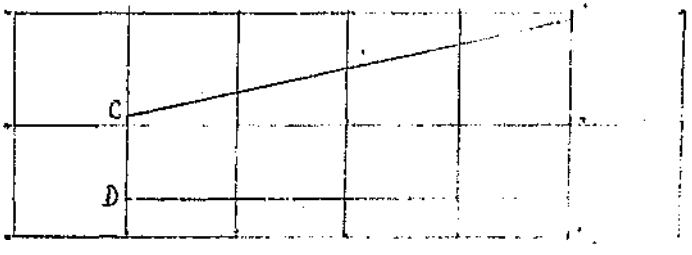
(a) C is longer

(b) D is longer

(c) C and D are the same length

(d) You cannot tell

Fig. 3.8. Test item for conservation of length



(Hart 1981 P.23)

Almost one third of the sample were unable to select the correct answer in this question.

(vi) Ordinal meaning. The ordinal meaning indicates the relative position within a set like third, seventh etc. The acquisition of these words lags far behind the cardinal ones according to Fuson and Hall (1983, p.86). Piaget investigated this topic under the study of "seriation" using sticks, dolls etc. and he showed the

ordinal ability occured at about 6 to 8 years (Ginsburg and Opper 1969, p.141). The learning of the ordinal words is not the end of the matter however because children must come to understand the relationship between two ordinal numbers and be able to compare for example the "ninth" and the "fifth". Two ordinal positions can be accurately compared by the use of one of the three relations: less than, same as, greater than (Fuson and Hall 1983, p.90). These authors say they have been unable to find any research into conservation of ordinal number.

(vii) Coding and categorizing devices. There is still another use of number in our everyday language and that is coding and categorizing devices in which we use the number to designate an object (e.g. bus number 204). This use of number is a non-numerical one and the number words or number symbols are used simply as identification names (e.g. telephone numbers, football jersey numbers etc.) (Fuson and Hall 1983, p.93). This may be a source of confusion for young children and might undermine the child's progress towards understanding the numerical meanings (ibid).

The present research attempts to explore the factors associated with mathematics performance among the Tswana students of the Bafokeng region. Outlined above are some of the ways numbers are commonly used. It was investigated whether students had mastered these meanings

or whether lack of clear understanding of these meanings prevented students from solving certain types of arithmetic problems. Students' knowledge of the number line was also investigated. Lastly the Tswana language itself was analysed for its number vocabulary in order to find out if it is possible for Tswana students to abstract number concepts in their home language.

3.3.3. Developmental Stages in Number Learning

Dickson et al (1984) present the work of Schaeffer, Eggleston and Scott (1974) as a framework to look at how children aged 2 to 6 years master counting in both its cardinal and ordinal aspects. They tested 65 American children using objects like toys, sweets and signals like drum tapping. All the tests were carried out orally. They proposed the development took place in four stages:

Stage 1: Pre-counting. Children in this stage have mastered the cardinal aspect of numbers up to five but do so by a pattern of perception rather than counting. In Piaget's stages of development of conservation of number arising out of experiments done in the 1930's, he referred to a first stage of "global comparison" which corresponds to Schaeffer et al here (Dickson et al 1984, p.184).

Stage 2: Ordinal aspect. Children could count up to 5 but had not mastered the cardinal aspect i.e. they were

not able to respond correctly with the largest number counted as the answer to the question: How many? All the children pointed when counting and they obviously struggled with keeping track of which numbers were already counted.

Stage 3: Cardinal aspect. Children could count up to 10 and had mastered the cardinal aspect as well as the ordinal i.e. they could count successfully say 8 object) and they knew the largest number counted was used as a name for the whole collection (ibid., P.174).

Stage 4: Relative size of numbers. Children could tell which number from 1 to 10 was larger than any other. This would seem to be similar to Piaget's 3rd stage in which one-to-one correspondence with lasting equivalence has been reached i.e. children recognise that 6 glasses is equivalent of 6 bottles even when one is grouped close and the other is spread apart (ibid., P.185).

The authors say results of research by Gelman and Gallistel (1978) support the general findings of Shaeffer et al given above.

Piaget found the under 7 year old pre-operational child couldn't do the tests on conservation correctly because of what he calls "decentration" by which he means the pre-operational child still centres on one particular property (length for example) whereas the older child has "decentred" and can focus on more than one property simultaneously. There are some general criticisms of

investigations described in this section which could apply equally well to Piaget or to Schaeffer et al. Firstly they were all verbally administered and hence language may have been a problem (Donaldson 1978). Secondly it has been alleged that the situation predisposes children to answer incorrectly (ibid). Finally using two sets of different objects introduces the concept of transitivity and therefore is not a good test for the invariant property of number (Dickson et al 1984, p.186). There is however agreement that in order to really understand and apply natural numbers, an appreciation of both cardinal and ordinal aspects is needed, together with the necessary relationships between them (Resnick 1983, p.147).

3.3.4. Arithmetic operations

All the research available for the present survey considers addition, subtraction, multiplication and division to be the four basic arithmetic operations. Piaget however suggests that conservation, seriation and class inclusion are more fundamental still and the last named, class inclusion he sees as a step from mere counting to number manipulation. By class inclusion he understands the simultaneous recognition of a total class and one of its sub-classes as for example 5 objects can be 1,2,3,4,5, in its own set and when added on to a set of 4 objects this old set of 5 will now be 5,6,7,8,9.

These three operations Piaget regards as essential to handling numbers and he thinks they are achieved simultaneously at about age 8 (Dickson 1984, p.188). Resnick (1983) calls this a part-whole schema whereby children can think of numbers as compositions of other numbers (e.g.2;5;7) in this group 7 is the whole and 2 and 5 are the parts. This enables the child to solve a series of problems like: Sam had 5 apples, Sarah had 2, how many is this?, and even very difficult ones like: Peter had some marbles Dav gave him 5 more for a game, now Peter has 7 marbles, how many marbles did Peter have at the start? Resnick believes children move away from the "mental number line" (see 3.3.2. above) to the part-whole schema at about age 7 or 8 years (Resnick 1983, p.115).

Carpenter and Moser (1983) quote a lot of research which shows that the development of basic number concepts involves the integration of basic quantitive skills such as counting, estimating and subitizing, by which is meant the direct perception of numerosity. These authors say most of the current research in this area is looking more at the processes children use to solve arithmetic problems (P.14).

What follows here is a review of research into the meaning of addition, subtraction, multiplication and division and then the strategies used by children in these operations. The reasons for this concentration on the

operations is the phenomenon observed by the present researcher that among Tswana students there is a fair measure of ability in computation skills but they are often at a loss to know which operation to use. Several authors like Carpenter (1981), Vergnaud (1982), Brown (1981), Carpenter & Moser (1983) claim some of children's difficulties in ma..s can be traced to initial instruction in addition and subtraction and that the concept of additive structure underlies a large portion of mathematics (P.8)

3.3.4.1. The meaning of the operations

Dickson et al (1984) provide the following stages of development according to Grossnickle (1959): children first grapple with a meaning of the operations in concrete terms, later they learn simple computation and finally arrive at an understa..ng of the structural properties of the operations (P.221).

Brown (1981) investigated children's understanding of the four basic operations by testing the children's ability to select the correct operation in a given problem and by asking the children to supply a word problem for a given operation. She noted ..at for quite a number of her sample understanding was limited to "key words": altogether (=add), share (=divide), times (=multiply) and the children used these as cues for selecting one operation rather than another (P.23). Brown gives the following models for each of the

operations:

(a) Addition: It may viewed as a unary or binary operation. In the former case (i) adding-on is a unary operation e.g. I had 5, I got 7 more. How many now? As a binary operation there are (ii) union e.g. I have 5, you have 7. How many? (iii) comparison e.g. I have 5 more than you, if you have 7 how many do I have? and then other variations such as directed lengths in opposite senses and mixed variations of adding-on, union and comparison may occur. The direct adding-on type problem proved easiest for all the sample tested by Brown (1981, P.27).

(b) Subtraction: There are two unary models: (i) take-away e.g. I had 13, I removed 5, how many left? and (ii) complementary addition e.g. How many do I add to 5 to get 13? There is just one binary model: (iii) difference e.g. I have 13, you have 5 how many more do I have than you? Brown found the take-away model easiest for the children to manage (P.29).

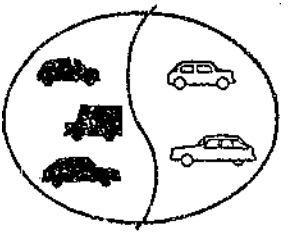
Dickson et al (1984) present just two models for addition and subtraction:

(i) discrete objects as in fig. 3.9. and (ii) continuous lengths as in fig. 3.10.

Both of these models can enable children to visualise problems of the following types: 3 + 2 = 5; 5 - 3 = 2; 5 - 2 = 3. These authors say very little research has been done into the children's ability to solve word

problems (P.221). The classification of addition and subtraction problems done by Carpenter & Moser (1979) and Vergnaud (1982) shows that simple "adding-on" problems are easiest and vector subtraction the most difficult.

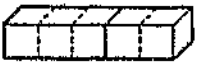
Fig 3.9. Model for addition based on discrete objects



$3 + 2 = 5$
$5 - 3 = 2$
$5 - 2 = 3$

(Dickson et al 1984 P222)

Fig 3.10. Model for addition based on continuous lengths



$3 + 2 = 5$
$5 - 3 = 2$
$5 - 2 = 3$

(Dickson et al 1984 P222)

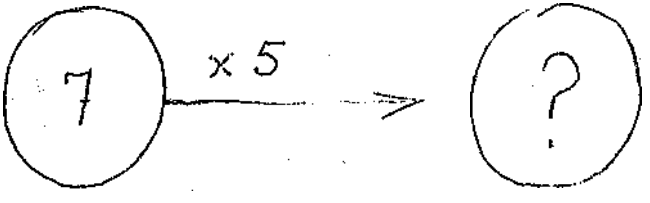
Vergnaud (P.39) reports a success rate as low as 25% for

a sample of 11 to 12 year olds for vector type subtraction problems such as: This morning John lost 2 cars, at tea time he had 3 more than he had at breakfast, how many cars did he find this afternoon? These findings are similar to those of Brown quoted above (op.cit. P.223). Now to return to Brown's models:

(c) Multiplication: Brown presents four models:

(i) multiplying factor e.g. I have 7, you have 5 times as many, how many do you have? This is a unary operation, illustrated in fig. 3.11.

Fig. 3.11. Multiplying factor for multiplication

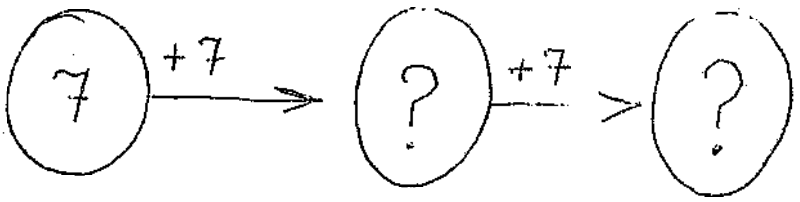


(Brown 1981)

(ii) repeated addition e.g. I got 7 every day for 5 days, how many do I have? This model is shown in fig. 3.12.

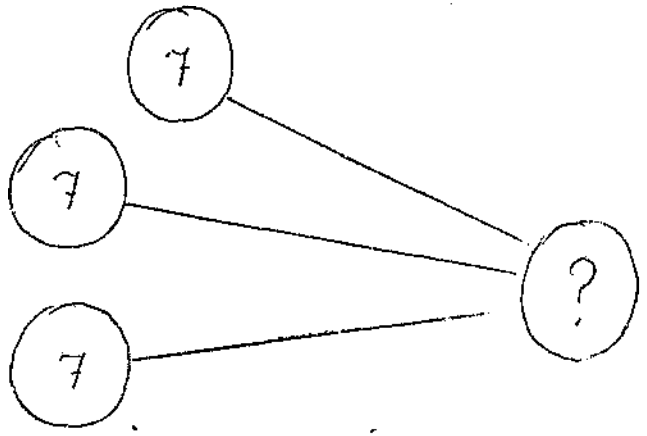
(iii) rate e.g. there were 5 people, each had 7 apples, how many is this? Brown gives a diagram, illustrated in fig. 3.13.

Fig 3.12. Repeated addition model for multiplication



(Brown 1981)

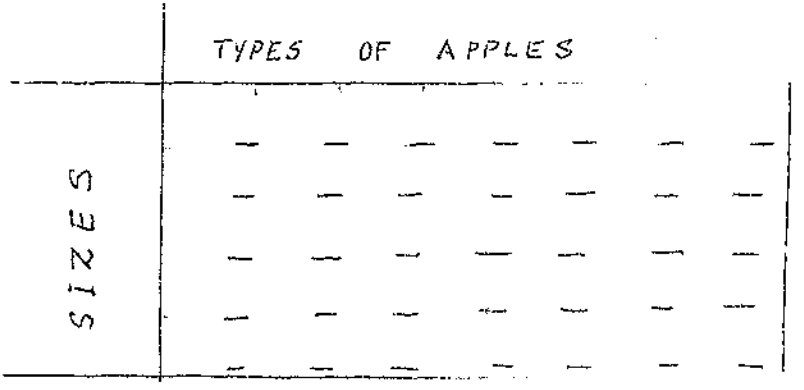
Fig 3.13. Rate model for multiplication



(Brown 1981)

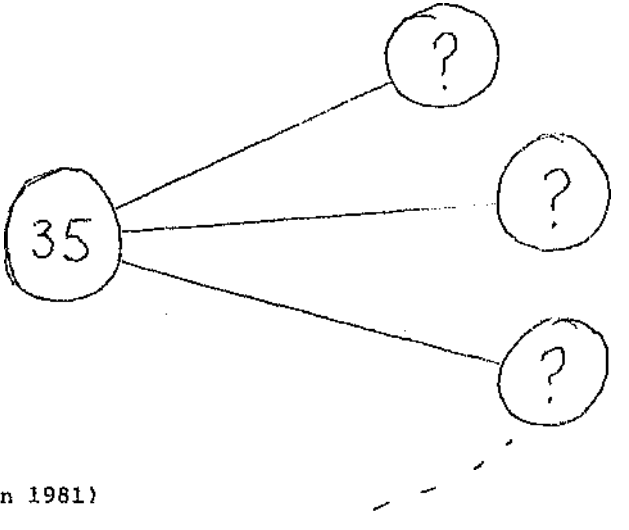
(iv) cartesian cross product e.g. 7 different types of apples, each type graded into 5 sizes, as shown in fig. 3.14. How many different sorts of apple can you ask for?

Fig 3.14. Cartesian cross product model for multiplication



(Brown 1981)

Fig 3.15 Model for division based on sharing



(Brown 1981)

As to be expected the repeated addition model was the

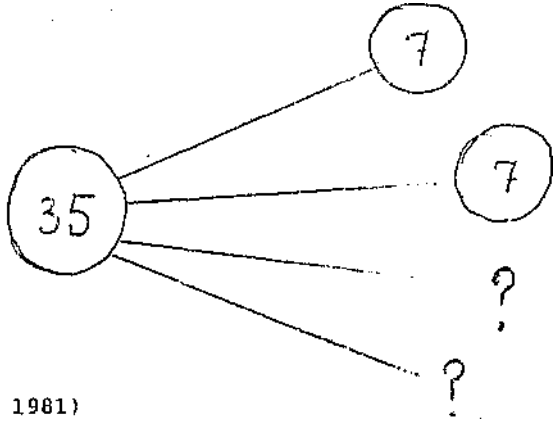
easiest for the children to manage (Brown 1981, P.30).

(d) Division: Brown has three models for division which are:

(i) sharing e.g. I had 35 apples and shared equally with 7 people, how many each ? In this model we are focussing on the number of apples in each group as shown in Fig 3.15

(ii) grouping e.g. I have 35, I want to give 7 to each person, how many people will get a share ? Here it is the number of groups which is counted as shown in Fig 3.16

Fig 3.16 Model for division based on grouping

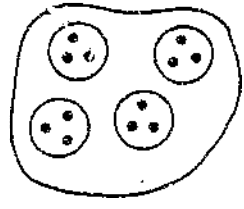


(Brown 1981)

(iii) continuous quantity e.g. 7 people is an example of a discrete quantity whereas 7 metres is continuous, so dividing a measured quantity where the result may be a fraction or a decimal introduces a new level of

difficulty. The easiest kind of problem was the simple sharing. Several students used a strategy of repeated addition which enabled them to get the right answer but Brown says they didn't really understand multiplication or division (P.33). Dickson et al (1984) present three models as alternative concrete interpretations for multiplication and division thus: 3 x 4 could be visualised in any one of the models shown in Figs 3.17, 3.18, 3.19.

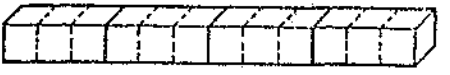
Fig 3.17 Model for multiplication based on discrete objects



(Dickson et al 1984 P.234)

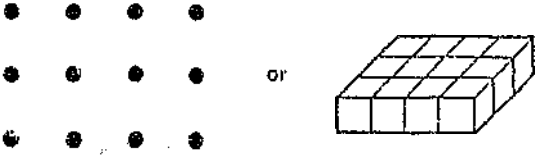
These authors claim that most studies show the meaning of multiplication and division is much more difficult for children to grasp than addition and subtraction. They refer to the work of Dienes (1959) who gives an example of a child comparing a one block arrangement with a four block arrangement as shown in Fig 3.20.

Fig 3.18 Model for multiplication based on continuous lengths



(Dickson et al 1984 P.234)

Fig 3.19 Model for multiplication based on cartesian product



(Dickson et al 1984 P.235)

The child will mentally build on three more blocks and he is unlikely to consider the larger one as being four times as long as the smaller one (Dickson 1984, P.231).

Fig 3.20 One block compared to four block arrangement



(Dickson et al 1984 P.231)

Hart (1981) found that over 30% of secondary school children choose to add rather than to multiply when solving ratio problems (P.91). Brown (1981) found that most 11 year olds were unable to make a story to match the expression 84 x 28. She goes on to compare the results of her studies on the four operations and says the order of difficulty was: +; -; ÷; x; multiplication being the hardest for children to comprehend. At the end of first year in secondary school at approximate age of 12 years the study indicates that:
30% have a sound understanding of the number operations; 20% are fairly good but have difficulty making stories to match multiplication and division; 10% have a very poor understanding of the operations multiply and divide but they can use addition based stategies to get solutions; the remaining 40% are at various stages in between (ibid P.42). Dickson et al (1984) also report

that research shows division may be easier for children than multiplication (P.235). These authors also highlight the importance of children being able to recognise which of the four common number operations is appropriate in solving a given number problem since many children have not achieved this ability on entry to secondary school (ibid P.237). Brown (1981) also sees this recognition of the proper operation as important in teaching mathematics especially since the widespread use of calculators in stores and even in schools. When she extended her tests to decimals Brown found tremendous difficulty even for 15 year olds in recognising the correct operation and less than 10% of these students would be consistently able to press the buttons on a calculator in the correct order for division (Brown 1981, P.47). Karplus et al report similar findings about the relative difficulty of basic operations for adolescents solving proportion problems except that they found division to be the most difficult (Karplus et al 1983, P.46). The understanding of the four basic arithmetic operations in an African context may be further hindered by language problems as described by Gay & Cole (1967) in their Liberian study:

> .... we observed Kpelle use of arithmetical operations similar to addition, subtraction, multiplication and division in Western arithmetic. The first important fact is that the Kpelle recognise no abstract arithmetic operations as such. They put objects together, take objects away, put like sets of objects together, or share objects among sets of people; they have no occasion to work with pure

> numerals. All arithmetical activity is tied to concrete situations (Gay & Cole 1967, P.50).

It was necessary in the present research to examine whether or not Tswana students could select the correct operation to solve the given problem as reported in Chapter 6. From the discussion above it appears that many children latch on to verbal cues such as "altogether" for "add or multiply". Therefore the use of such words had to be avoided as far as possible. The first step then was to establish whether or not a student could select the correct operation and the second step was to find out if there was a significant correlation between this ability and performance in mathematics.

3.3.4.2. Strategies used by children

This is an area which has received a lot of attention from researchers in maths education during the past twenty years. Before that the psychological theories underlying research thought of learning as a direct product of the external environment but since the work of Piaget it is now generally accepted that internal cognitive processes must also be investigated (Carpenter & Moser 1983, P.11). These authors say that modern research is on the processes (i.e. how do children solve arithmetic problems). There are three approaches used in such studies: (i) individual interviews (ii) response

latencies in which the time for each step is measured and (iii) analysis of error patterns (P.18). Ginsburg et al (1983) distinguish between the clinical interview of Piaget and the talking aloud method used by Newell & Simon (1972) where there is very little interference by the researcher (Ginsburg et al 1983, P.8). Carpenter & Moser (1983) agree that the interview provides the most direct measure of the processes that the children use but they also mention several drawbacks like: children may be unable to explain the process used; interviewer may exert undue influence on the child; the method relies greatly on the subjective judgement of the interviewer etc. (ibid P.19). Some of these criticisms are upheld by Lesh et al (1983, P.282) but they also agree about its usefulness, as do Ginsburg (1983) and Lester (1983, who advocates a variation which he describes as "thinking aloud" (Lester 1983, P.231). Dickson et al (1984) say that children reach the stage of strategy development between 6 and 8 years of age. They refer to research done by Carpenter & Moser (1979; 1982), Ginsburg (1977) and by Steffe, Thompson & Richards (1982). Carpenter & Moser found the following:

(i) counting-all: either with models or with mental images;

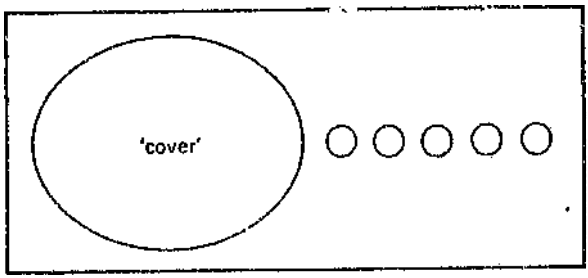
(ii) counting-on: either from first set or from larger set;

(iii) number-recall: either learnt fact or derived num-

ber fact.

They noted that over an 8 month observation period there was a gradual movement away from the counting-all using concrete objects to the more abstract level of recalled number fact. One very interesting point made by Carpenter & Moser is that hardly any children used the wrong operation, a mistake very common with older children. Dickson et al (1984) reports how Steffe et al (1982) and Ginsburg (1977) classified children into categories as a result of a simple test which involved using discs as shown in Fig 3.21

Fig 3.21 Covered disc test for counting



(Dickson et al 1984 P.193)

The children were told "there are 3 discs under here - how many on this board ?" The categories were:

(a) perceptual counters - depended on presence of concrete objects and were unable to answer correctly in a

consistent manner;

(b) figural counters - could picture objects under the cover mentally;

(c) motor counters - could count motor actions like pointing a finger;

(d) verbal counters - able to count verbally but always started at "one";

(e) abstract counters - able to count on from end number of the hidden discs. (Dickson et al 1984, P.192).

Resnick (1983) reports that even pre-school children have their own methods of forward and backward counting to solve simple problems, and that later on doubles like 2 + 2, 5 + 5 are solved particularly quickly. Some students use an adaptation of this to derive number combinations as for example 3 + 4 they work 3 + 3 and add one to get 7 (Resnick 1983, P.117).

Carpenter & Moser (1983) present the following strategies for addition and for subtraction:

(i) addition strategies:

Strategy 1: Finger counting. The fingers or other physical objects are used to represent each addend, then the union of the two sets is counted starting from one. There are three possibilities in this: (a) physically join the two sets before counting (b) counting without joining the sets physically or (c) physically construct one set and then increase this set by counting in the elements of the second set without actually constructing

it. This analysis is based on the work of Weaver (1982) says Carpenter & Moser.

Strategy 2: Counting sequences. The child counts right through the sets without the use of physical objects or fingers. Suppes & Groen (1967) note that this can be done by counting from "one" each time whereas Groen & Parkman (1972) note counting on from the first set is an advance and counting on from the larger is better still.

Strategy 3: Recall of number combinations. This is what we know as "tables" or other memorised facts. children may use the memorised fact itself or they may use memorised facts to derive new facts (Carpenter & Moser 1983, P.20). Fuson (1982) remarks with reference to the counting-on strategy above that it represents a major advance in the child's arithmetic ability. The reason given is that it involves the problem of converting from a cardinal number representing the size of the initial collection to an ordinal number representing the final count word for that collection (Dickson etal 1984, P.196).

Carpenter & Moser also list six subtraction strategies: remove from, remove to, adding on, matching, choice (i.e. counting up or counting down), and recalled number facts. Regarding the stages in the development of levels of abstraction these authors regard as a primitive stage where children model the action or relationship using physical objects or fingers. At the next

level they use counting sequences and research indicates that even up to the 7th grade 30% to 40% continue to use this strategy. Recalled number facts or derived number facts is the highest level of abstraction and the authors claim:

> To learn number facts at a recall level remains a viable goal of the mathematics curriculum, and most students eventually attain this level (Carpenter & Moser 1983, P.31).

Fuson & Hall (1983) point out that there is still a higher level namely the idea that addition and subtraction are inverse operations. This of course contributes more flexibility to children in their solution of addition and subtraction problems (ibid P.99). Weaver (1982) claims that the inverse process assertion is erroneous (P.62). However Weaver's definition of addition and subtraction (P.61) is much too theoretical to shed light on the present research. Hence both addition/subtraction and multiplication/division are treated as inverse processes.

There is still a great deal of material reviewed by Lesh & Landau (1983), Ginsburg (1983) and Dickson et al (1984) on multiplication and division but sufficient has been presented above to indicate the general trends in research on strategies used by children in working arithmetic problems. In the present research strategies used by students in the application of addition, multiplication and division were observed and recorded

during personal interviews and results are given in Chapter 6. The previous research indicates that various levels of abstraction can be deduced from the strategy used and it was important for this research to find out if there were significant correlations between the strategies used and performance in school mathematics.

3.4. Third world mathematics research

In the third world countries social reform brought about by efforts at economic expansion and desire for a better living style forced people to look at the schools in terms of investment and to begin to measure output. This "input-output" model is used by Alexander and Simmons (1975) in their analysis of 3rd world research into determinants of school achievement.

At the same time academics tried to apply psychological measures such as I.Q., R.F.T., Embedded Figures, Conservation Tests and so on to underdeveloped societies and noted how badly their subjects fared in comparison to Western subjects. Okonji (1969 and 1971) worked in Uganda and Zambia using Piaget type tests and he applied Witkin's ideas using African subjects. Wober (1966 and 1967) experimented with the Rod and Frame tests and Embedded Figures, in Nigeria. Dawson (1967a and 1976b) examined spatial perception in Sierra Leone. For a time there seemed to be a spectre haunting the wings - per-

haps people in these non-technological cultures just couldn't do maths ?

In the foreword to Cole et al (1971) G.A. Millar speaks about a persistent myth that pervades Western culture. Many westerns seem to think that non literate people in less developed countries possess a "primative mentality" which is inferior to their own advanced or highly developed mentality. By comparison the former would be concrete rather than abstract, rote rather than general, illogical rather than logical, childish and emotional rather than mature and rational (ibid P.vii).

It was then that the researchers began to examine the assumptions which underlay the testing and they began to note how culture bound they really were (Siann & Ugwuegbu 1980), (Serpell 1975), (Michau 1978).

Tests developed in a western context and applied directly in a very different cultural context may lead to false conclusions and the poor performance of the primitive people has been interpreted as a sign of their inferior mental abilities (Millar in Cole et al 1971 P.viii).

The work of Cole and associates (1967 and 1971) with the Kpelle and Bishop (1983) in Papua New Guinea opened up whole new vistas, for they discovered that when local materials were used and meaningful test items were included their third world subjects performed as well as, and in several instances better than, their Western

counterparts.

The Tswana people are not alone in poor performance in mathematics - it seems to be a universal problem. Certain investigations have been carried out to try to understand why students in non-technological cultures have difficulties and to examine whether there are cultural reasons for this. Two such works, namely those of Gay & Cole (1967) and Bishop (1983), are summarised in 3.4.1. below. There have been a number of mathematics projects started to try to reduce the huge percentage of failures in school mathematics in developing countries. Two of these are reviewed in 3.4.2. from evaluations carried out by Cundy (1977 and 1978). Cundy reports one as being highly successful and the other an outright failure. For comparison it was decided to include one report from a first world country in 3.4.3. which describes the state of mathematics in some English schools, because it shows that the difficulties associated with mathematics teaching and learning are not unique to undeveloped countries. What is however unique is the reliance in these countries on imported ideas, imported tests, imported models. It is clear that there is a need to begin to develop theories based on their own real experiences and before this can happen there must be accurate description of mathematics teaching and learning and especially of the cognitive processes taking place. In South Africa a start has already been

made by the Human Sciences Research Council and MATIP, a branch of the Research Unit for Education Systems Planning in the University of the Orange Free State. The H.S.R.C. reports on mathematics and the MATIP work are reviewed in 3.4.4.

3.4.1. How culture and mathematics are interrelated

This topic is receiving more attention in modern research as can be seen from such reviews as Brewer & Haslum (1986) on Ethnicity, and Carrier (1984) on the nature-culture debate in accounts of unequal educational performance.

The present section confines itself to just two pieces of research one done over several years in Liberia and the other carried out in Papua New Guinea. It was found that the work of Gay, Cole and their fellow workers in Liberia and the work of Bishop and others in Papua New Guinea were very helpful for guiding the present research.

3.4.1.1. Liberia

Gay, Cole and others have undertaken some very fundamental research among the Kpelle of Liberia who were found to experience a great amount of difficulty with the western style mathematics and the object of the research was to find out what kind of mathematics existed in the Kpelle culture. The findings were published in two

major volumes:one in 1967 which was more tentative and exploratory; the other in in 1971 which is more analytic and assumptions and methodology receive deeper treatment. Both of these are reviewed below.

(a) The new mathematics and an old culture

This is a study of learning among the Kpelle of Liberia by John Gay & Michael Cole (1967). The authors demonstrate how the traditional Kpelle culture, based on the cycle of rice production in Liberia, affects the learning readiness and even the very thinking of children who are being taught concepts for which there are no exact antecedents in their culture. It highlights the areas of conflict between Western-type schooling and local belief and practices and it tries to arrive at an understanding of how these affect the learning of mathematics.

The authors give a very exhaustive account of the Kpelle language vis `a vis Western mathematics and they point out that many words and terms "missing" from that language which lead to learning difficulties. On the other hand they show certain strong points of the Kpelle when the subject matter is related to their own lives. Just one example of this is the high accuracy of a Kpelle sample who were asked to estimate the number of cups of rice in a bowl and the very poor performance of an American sample when presented with the same problem (P.65).

Gay and Cole used Piaget-type problems in order to try to identify mental structures and visual patterns and they describe some of these in Chapter 6. The authors conclude:

> Kpelle students who encounter mathematics in Western-orientated schools misuse the English language, learn by rote memory and guessing, do not use logical patterns, and have no use for what they learn ... school mathematics has largely failed ... His teachers know something is wrong, but they do not understand enough to propose a coherent course of action (P.35).

One difficulty about the experiments using the interview technique was that the Kpelle students could not easily explain the reason for an answer they had given or state the general rule underlying the solution of a problem. Skemp (1979, P.175) proposes a framework which might apply to this situation when he speaks about intuitive and reflective functioning of intelligence (see Fig. 3.2. in section 3.2.4. above). The Kpelle difficulty may be understood in terms of their not having well-developed reflective functions due, as Gay and Cole (1967) imply, to the Kpelle culture where tradition and respect for authority are the dominant values (P.88). Some attention is paid to how the Kpelle learn new ideas and the authors relate fast learning to the ability to use a verbal label whereas slow learners do not use such a label (P.86). The authors are at pains to point out that many of the western cognitive constructs such as concrete and abstract thought processes, are inap-

propriate for understanding the Kpelle because the tasks used to provide data may very well be meaningless for these people. One example given concerns a sorting experiment (Pp 36-40). The task was constructed to test the ability to form sets of objects according to the attributes of colour, number and form. Subjects were given eight cards on which were pictured triangles and squares either red or green and there were either 2 or 5 on each card. The subject was asked to sort them into two groups (P.38). The results were astonishing. The task was almost impossibly difficult for all Kpelle subjects but very simple for Americans. The authors suggest a possible explanation lies in the way sets of objects are normally categorized and classified in the Kpelle language and culture (P.39). There is no activity among the Kpelle for classifying "nonsense materials" such as coloured shapes and cards bearing numbers of these shapes (P.40).

Two different models of mathematics can be detected throughout the research. The first one has been described in the previous chapter, section 2. as the "reification model". This is the model the Kpelle teachers and students seem to be working with (Pp 33-34). The second has been described in chapter 2, section 2. as the "interaction model". This is the model regarded by Gay and Cole as the ideal to be aimed at (P.93).

(b) The cultural context of learning and thinking

Gay and Cole co-authored this book with Glick and Sharp (1971). The research topic is the same as that of the previous work discussed above namely the problem of mathematics in Liberia. Their approach was to find out what mathematical structures and concepts existed in the Kpelle language and culture:

> ... if we know more about the kinds of mathematical knowledge that these children bring to school might we not be in a better position to teach these children the kind of mathematics we wanted to teach them ? (P.xi).

In discussing the influence of culture on thinking the authors draw on three disciplines viz. anthropology, psychology and linguistics and they attempt to abstract the basic concerns of these three disciplines in the study of culture and cognition. From anthropology they came to realise that cognition cannot be studied isolated from its cultural context and the investigator must not impose his own categories of experience on the phenomenon being studied. In psychology the process of cognition and not the mere content, is what is studied and therefore in their research the emphasis must be on ways of classifying revealed in experimental situations; thinking is defined in terms of new combinations of past experiences and is always goal orientated. Linguistics indicates the cognitive capacities of the individual are reflected in his language and the cognitive processes of the speaker are as complex as the language he speaks

(P.18 ff). One of the assumptions questioned by the authors is that based on an evolutionary model of society which can be stated thus:

> ... society is evolving and simultaneously progressing toward a literate technological state like that of the west ... and primitive adults represent an early form of the adults of advanced societies and the primitive adult is equivalent to the civilized child (P.5).

Cole et al reject this model and they claim the thought processes identified in primitive cultures are not at some lower stage in the development of the human mind. Instead they represent different strategies by which men make nature accessible to rational enquiry. Both western and non-western strategies seek objective knowledge of the universe; both proceed by ordering, classifying and systematizing information; both create coherent systems (P.8). The authors were thus led to a statement of an important principle for their research: they believed they were always dealing with normal human beings whose behaviour is organised and meaningful within its natural context. Whenever therefore they encountered "inappropriate behaviour" they have made this the subject of further investigation and not simply judged it a proof of inferiority (P.24).

The rest of the book recounts the research into what the authors consider to be the most fundamental cognitive structure in any culture namely the classification system. They adopted a two-fold approach to the study

by looking first at the Kpelle language and focussing on the classification of natural-world objects in the Kpelle noun system; and then they devised a series of experimental situations in order to observe what criteria were used by the Kpelle in their clustering of items. Among the more important findings were (i) the way things are classified in verbal behaviour and the classifications that occur when real objects are present are not always the same and (ii) the criterion most often used by the Kpelle was that of function and use whereas western children normally relied on some visual attribute such as colour, shape etc. (P.79). As a result of their findings the authors conclude that the factors which materially affect categorization are:

a) the degree of structuring in the task;

b) the nature of the stimulus materials;

c) the experiences of the subject population

(P.92).

The investigators then proceed to explore how classification affects learning, memory and logic in chapters 4, 5 and 6. The major conclusion of Cole et al is that cultural differences in cognition reside more in the situations to which particular cognitive processes are applied than in the existence of a process in one cultural group and its absence in another (P.233).

There are some very important implications for the present research into mathematics among the Bafokeng

that arise from the brief discussion given above. As regards methodology it is clear that the research would have to follow the lead given by Gay and Cole (1967) and Cole et al (1971) in their use of experimental anthropology as a broad approach. This approach can be summarised as consisting of multiple experiments emphasising patterning of results; locating the experiments within cultural contexts; always keeping in mind that the subjects are normal human beings with well developed hypothetical thinking and mental strategies (P.182). As a result of the research into the Kpelle culture great care would have to be exercised in the present research among the Bafokeng when using tests in experimental situations. It was important to try to understand how the test is perceived by the subjects and what cognitive processes are taking place. It was necessary to explore the Tswana language to see how it deals with number and to find out if mathematical concepts exist in that language. This material is reported in chapter 7.

3.4.1.2. Indigenous mathematics project - Papau New Guinea

The original project is described by Lancy: in the Papua New Guinea Journey of Educationno. 14. There is a summary account in Lesh & Landau (eds) (1983). Alan J. Bishop spent three months working at the University at

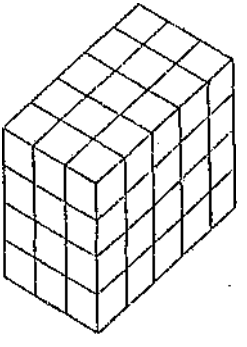
Lae, New Guinea where there is a thriving mathematics education centre. Bishop concentrated on the problems surrounding the students' difficulties with geometric and spatial ideas in mathematics and science. This item is included because it can be seen as a development of the visual perception discussion in 3.2. above where Wober compared the American visual sensotype with the African sensotype which was more proprioceptive and auditory. Here Bishop distinguishes between the visual as interpreting figural information and the visual as processing and he found his subjects to be much stronger on visual processing than Westerners.

Bishop administered a group test of problems involving diagrams and other visual representations in mathematics but with very little mathematical knowledge required in their solution. The test contained a lot of 2-d pictures of 3-d situations using conventions like dotted lines for hidden edges, perspective, cross-sections, nets for solids et.c. His subjects consisted of 250 first year students at the University of Technology. In order to deal with the problems the students had to: (i) read the words and understand them (ii) read and understand the diagram (iii) imagine the situation thus described (iv) imagine what changes if any, needed to take place (v) represent the results either in symbols or in a diagram. Generally the test was found to he very difficult. A sample test item given by Bishop

(1983, P. 187) shows 60 stacked cubes on a base 5 x 3 at an angle as shown in Fig 3.22.

Fig 3.22 Stacked cubes test

This is a diagram of a cuboid made of small cubes. If the OUTSIDE of the cuboid is painted red, how many cubes will have only one face painted? (14% of the students were successful) (See Schema 6.1.)



SCHEMA 6.1

(Bishop 1983 P. 187)

It was accompanied by these words:

> "This is a diagram of a cuboid made of small cubes. If the outside of the cuboid is painted red, how many cubes will have only one face painted?

Only 14% of the students were successful in this item. It was then decided to interview a small sample of 12 students to explore the difficulties experienced in the test. 4 students from each of three different cultural environments were selected. All were male. English was used throughout. Bishop says his research was exploratory and hypothesis generating. During the interviews tasks such as the following were worked:

a) map drawing of students' local area - well done;

b) copy drawings - not good, students lacked skill in drawing and were very unclear about criteria for exactness;

c) spatial vocabulary translations (e.g. translate "space" words like: above, below near et.c. into home language) - only 15 out of a total of 71 words could be translated by all twelve subjects;

d) construct models from drawings - some had difficulty in reading perspective cues;

e) imagine a figure like a triangle, label it mentally, picture which is the largest angle, shortest side et.c., then draw it - well done by all twelve;

f) location game with circles and axes - say where they are in relation to each other - some trouble with language in descriptions;

g) square mazes - well done - all succeeded;

h) camera location - identify the place from which a photograph was taken - very poorly done - one of the hardest tasks and it created a great deal of anxiety for many because they were unfamiliar with cameras and photographs;

i) visual memory task was excellently done by all - subjects were allowed to look at an array of 12 small objects in a 3 x 4 design for 45 seconds - pieces were then removed and subjects asked to replace them, retention in this task was also excellent as shown by the fact that they could repeat the design one day later and

some even after one week. Bishop comments on the visual memory displayed here and he noted that they worked slowly and deliberately. In contrast Bishop claims:

> The typical Westerner seems to prefer to work quickly, in fear of losing the memory.

Other tests were: block drawings, embedded figures, word completion et.c. The results were analysed by Bishop in terms of the constructs, abilities and meanings. Bishop (1980) had proposed two different types of ability constructs namely:

(i) Interpreting Figural Information (IFI) which relates to the form of the stimulus material such as graphs, charts, diagrams et.c. IFI concerns the reading, understanding and interpreting of such information. The sample was weak generally on IFI measures (e.g. constructing models from the drawings in 2-d as well as embedded figures and camera and photograph tasks). Bishop suggests this is due to lack of experience with many types of visual conventions and representations common in Western culture. Bishop quotes Lean (1981) who thinks it is a relatively simple task to train for IFI since it is mostly convention.

(ii) Visual Processing, (VP) which relates to the process of dealing with images and not the form of the stimulus itself. It involves visualization and the translation of abstract relationships and non-figural information into visual terms. Bishop found his sub-

jects to be strong generally on VP measures like maps, imagination and visual memory. Bishop suggests they solved these problem tasks visually and not by any verbal or symbolic coding and they tended to use a very visual Gestalt-like approach rather than an analytic stepwise one. Bishop again quotes Lean (1981) who says it is very difficult to train for VP ability in older subjects.

Language in all the interviews proved to be a confounding variable because it was often impossible to separate conceptual limitations from linguistic confusion. He refers to Berry (1971) who remarked on cultures with strong spatial skills having rich spatial languages. Gay & Cole (1967) had made similar observations. Bishop (1983) gives a transcript of an interview showing this language difficulty - he asked a question about a garden thinking it was a simple area problem to be solved by multiplication but the subject had a different conception. Bishop asked which of two gardens the subject would prefer and he showed two rectangular drawings on paper each with length and width marked. The subject refused to say which one he would prefer because his choice would depend on many things like soil, shade et.c. Bishop says:

> Clearly this student's concern was with two different problems. Size of garden was a problem embedded in one context, rich in tradition, folklore and the skills of survival. The other problem - area of a rectangular piece of paper was embedded in a totally different cultural context. How could they involve

the same concept (Bishop 1983, P. 196).

In this project Bishop has highlighted some of the problems of teaching mathematics in less technologically orientated cultures and he has provided a very useful insight into visual perception studies by distinguishing between IFI and VP.

From the above discussion it will be seen that the present research must include visual material and the students; response to this material must be investigated. It seems that many conventions used in drawings and diagrams are not properly understood by non-western subjects and these conventions have to be learnt at some stage. It may well happen that a student who is not successful in school mathematics may simply be suffering from a lack of knowledge about how to interpret figural information. Another problem encountered by Bishop, Gay & Cole and others with third world subjects was their sense of realism which hindered them from dealing with a hypothetical problem. This too must be researched, for Tswana subjects. Again these researchers have highlighted the effect of culture on perception and how this can lead western investigators into false conclusions about intellectual ability of non-western subjects. This research must be designed in such a manner that cognizance of this danger is recognised and guarded against.

3.4.2. Maths Projects

3.4.2.1. The Caribbean Mathematics Project (1977)

This appears to have been a highly successful project as initiated by H.M. Cundy. The emphasis was on training the teacher as the agent of reform in order to renew the maths curriculum of the Junior Secondary schools. The strategy was to train the teachers by involving them in curriculum development. In order to identify where the students' mathematical need was greatest, five tests were given to the pupils - these were:

(a) survey test of arithmetic fundamentals;

(b) pattern recognition test in numbers and spatial figures;

(c) maths achievement test;

(d) maths attitude test;

(e) questionnaire relating to pupils' and parents' education.

The result of these tests showed that the need was everywhere, but at least the project started by knowing something of the real situation.

There is no apparent overall model of intelligence, no model of learning, only a model of curriculum development, namely social interaction. It is assumed mathematics is a body of knowledge (as in the British maths for the majority project) and an accumulation of skills in manipulation and artificial problem-solving.

3.4.2.2. The Lesotho Mathematics Work-card Project (1978)

The summary of this project is based on an evaluation report by H.M. Cundy, published by the British Council and occasional references to it in HSRC Report No. 0.96 (1980). Neither the work-cards themselves nor the teacher manuals have been studied and hence everything written here must be regarded as tentative.

Cundy gives the following as reasons why the project was started: bad teaching, poorly motivated teachers, high failure rate in maths, overcrowded syllabus, students cramming too much maths without any real understanding, etc. It was decided that some form of individualised learning would help to remedy this situation and work-cards of the SMP were imported and given to selected sc' s in Swaziland in 1972 and to Lesotho and Botswana in the following year. In 1974 a battery of tests was given to the work-card classes which consisted of an intelligence test; test on maths content; word problem test; a five-dot test designed to evaluate whether the work-card students have increased their ability to use knowledge in new and slightly different situations. No statistically significant differences could be found between the work-card classes and the control groups other than in the five-dot test. Cundy lists the following as fundamental problems militating against the success of the project:

(a) Examination system

(b) Teacher shortages and changes

(c) Lack of adequate accommo.ation and resources

(d) Weaknesses in class teaching

(e) Weaknesses in individualized learning

(f) Human nature - laziness, avoidance of hard work, et.c.

Cundy claims that human beings are the same the world over - in England, China or Peru (P.9) and that virtues like honesty, hard work, punctuality, integrity, are common to all mankind - he implies that these are lacking in some of the schools or at least that they are subordinated to good examination results. On the credit side it is noted that some students have benefited - some weak pupils have been encouraged by their success at the cards and some of the abler pupils have enjoyed the faster rate of progress now open to them (P.22).

Van den Berg (1960) in Chapter 5, was highly critical of the project because it consisted chiefly of imported rather than home-designed material, as in the case of the Caribbean project, and secondly because it runs counter to the African way of life which is not individualized but communal.

No model or theoretical framework for learning is presented nor does there appear to be one assumed other than that the doing of exercises in mathematics is a worthwhile activity in itself and these exercises

should, as far as possible, be related to the locality. All the projects studied concern mathematics learning at the Junior Secondary level, all of them tackle a problem which seems to be poor performance of students in mathematics. All the students are required to do mathematics at this level and it would appear that some just cannot succeed. This raises several questions such as: Do they feel they don't need maths? Do they perceive maths as a school activity and not related to their lives? None of the projects have developed a theoretical framework which might be used in the present research. Gay & Cole (1967) question certain assumptions which are often underlying mathematics projects designed to improve the situation in the schools. These authors emphasize the importance of culture seen as traditional values and attitudes arising out of a certain economic way of life. They explore these in depth using small samples and the interview method.

3.4.3. Problems in Western schools

Mathematics for the Majority

British Schools Council Working Paper No. 14, written by Mr. P. Floyd. The pupils studied were those of average to poor maths ability and the aim was to assist teachers in designing a meaningful maths course for junior secondary school pupils with the stress on prepared teaching materials. In describing the situation at the time of

the investigation, Floyd notes among the drawbacks to effective maths:

(a) poorly qualified staff;

(b) lack of any equipment apart from chalk board and text book;

(c) harmful effects on classroom work due to pressure imposed by public examinations;

(d) very little subject interplay resulting in isolation of maths not only from other subjects but from everything outside of the maths class.

He says the effect of all this on students is that very few experience a stimulating maths environment and they don't have any great interest or enjoyment of maths... "most show dullness, dolorous docility and even apathy" (P.10).

The model Floyd seems to be criticising is one where maths is thought of as something external to the students and the teachers - it is viewed as a body of knowledge, rules, formulae, etc., which must be mastered as was discussed in Chapter 2 section 2.3.

3.4.4. South African mathematics research

3.4.4.1. Human Sciences Research Council (HSRC)

A considerable amount of investigation has been carried out by the HSRC into the problems faced by blacks in the RSA which they describe as "a technologically oriented Western type world", using the words of A.L. Kotzee,

President of HSRC, in "Preface to Groenewald" (1976) - Report No. 0-54. In this report Groenewald sets out to study the traditional cultural background of the "Bantu" child in order to determine what aspects of it are related to ineffective actualization of intelligence. The method was by analysis of the existing literature in order to identify aspects of black culture which hinder intellectual development (P.3).

In Chapter 2 some prominent aspects of the traditional educational environment of the black child are treated:

1. simplicity of the domestic environment;
2. narrowness of the educational aims;
3. externalisation of codes of behaviour;
4. emphasis on memory;
5. harsh discipline in the relationship to authority;
6. ineffective intellectual activation of the child by the parents;
7. lack of visible affective sharing between parents and children.

The author further classifies some noticeable aspects of the wider world of culture of traditionally oriented blacks under these headings:

a. The prescriptive pattern of their lives and the bondage of superstition (P.21);
b. The advancement of group orientation as a primary aim of the tribe (P.23);

c. The simplicity and concrete directed nature of the traditional way of life (P.24).

Chapter 3 has the main core of this report and it deals with the actualization of intelligence by the black child seen against the background of his traditional world of culture. Among those aspects of the traditional culture which may affect intellectual development are

i poor material environment;

ii ineffective orientation towards intellectual environment;

iii ineffective dissociation qualities;

iv closed learning situation;

v connection between learning intent and intellectual drive;

vi visual perception is hindered in the black culture;

vii dual nature of the relationship between school and wider cultural world - the one is not based on the other;

viii language of the school different from home.

Questions that arise from Groenewald's report which are appropriate for this research are centred around success in mathematics: is it related to SES of parents? (e.g. income, number of children per room, et.c.); is it related to western orientation of the family? (more individualistic, more objective attitude to life).

It is easy enough to understand what the author means by the traditional world of culture of blacks, but it is very difficult to know what period of history or which group of blacks he has in mind and there are great differences between, say, the pr arrogant Zulu fighters of Shaka and the friendly peaceloving Tswana and the diplomatic negotiators of Moshoeshoe's Sotho people. Groenewald further makes no effort to analyse how the economic and social forces at work in RSA over the past 150 years have combined to hinder black development in structures like land tenure, group identity, unsophisticated commerce. For example, in this context Davenport and Hunt (1976), quote an extract from Sir Teophilus Shepstone giving evidence to a commission in 1883. Shepstone speaks about the

> ... adaptability of blacks in Natal ... able to establish co-op companies for the purchase of individual farms ... understood the implications of land tenure and mortgage principles as well as trading as carriers, et.c. ... (P.38).

Certain strong points of blacks are also referred to by Groenewald (1976) like:

(i) highly developed audio perception (P.47);

(ii) group identification (P.23);

(iii) oral traditions (P.58);

(iv) ability to sustain laborious repetition e.g. in hard physical labour, in dance rhythms, et.c.

Van den Berg in Report No. 0-75 (1978) followed up on

Groenewald's work with his study of the black man's mathematical ability from a pedagogical perspective. The need for such research is the difficulty experienced by blacks in mathematical, technical fields and the prevalence among blacks of rote learning as against learning with insight and understanding which leads them to being unable to apply their knowledge in practical situations. This researcher has noted the same difficulty in his years spent teaching mathematics to Tswana students.

In Skemp's model of intelligence, "rote" would correspond to "instrumental" and "insight" to "relational" and thus present a structure within which data concerning the above problem can be organised in a theoretical framework.

Van den Berg attempts to describe those factors in (a) the education and (b) the traditional culture of blacks which contribute to the tendency to rely on rote learning. In Chapter 2 he refers to Groenewald's work and concludes that:

(i) blacks have a great difficulty in thinking abstractly;

(ii) language compounds this problem.

In Chapter 3 mathematical concepts and concept formation are treated. Van den Berg quotes Lovell (1971) P.14 as proposing that adults sometimes have concepts which they cannot define or verbalize but which may nonetheless be

adequate for everyday technical or professional use. In contrast to this, however, teachers are often deceived because children are able to use the appropriate verbal term while they have no idea of the concept involved. The reason for this error is because adults tend to impose their own cognitive structures on children.

In two other reports, No. 0-44 (1977) and Report No. 0-96, Van den Berg discusses methods by which the lack of success in mathematics among black children may be rectified - in the former report he suggests criteria for the selection and orderly arrangement of subject matter in mathematics and in the latter he deals with a group-orientated method of teaching as a means of promoting black pupils' insight into mathematics.

The research method in these reports is largely literature survey filled out with some interviews of overseers at certain gold mines and discussion with the training staff of Mamelodi Inservice Training Centre. There are no school-based data presented in these reports.

Any critique of Van den Berg's work must recognise that in his own words it is merely "an exploratory study" (Report No. 0-75: (P.80). However, there seem to be certain assumptions in these reports that need to be questioned. For example, the author assumes the situation in RSA to be equivalent to that of other countries like India, China and especially the African countries Nigeria and Ghana. But this researcher posits tremen-

dous differences - due to the political situation - between a black people striving for independence because they regard themselves as oppressed, as compared to a black nation grappling with their already achieved political independence and now faced with the realities of economic growth. An example of this difference can be detected in one of the slogans common in Soweto in the eighties: "freedom first, education later" (Christie 1985 P.245). Van den Berg assumes that education is a training that will fit the black worker / clerk / manager into the South African economic and industrial structure. But, the whole thrust of black school children since the 1976 unrest is a rejection of the status quo. Finally, Van den Berg rejects any diagnostic test procedures (P.65) in favour of expert-designed syllabuses. Presumably this will include teachers since he describes these as experts when he discusses the British and Scottish maths projects. But, it has often been pointed out, e.g. Hart (1981 P.209), that teachers tend to overestimate students' existing ability and furthermore students might view such a step as another example of the paternalism which has such negative associations for blacks because of its use in designing the hated Bantu education system.

There is still a need to meet individual students and to find out how they view mathematics and how it happens that some succeed and some don't. Van den Berg has

raised many issues - chiefly cultural - which are important for this research. However, it is the opinion of this researcher that much more has formed the minds of present black students than simply traditional culture. There is a state of crisis in the schools and the effect of this on values, attitudes and thinking of the students and how they cope with school subjects and particularly with mathematics has yet to be investigated.

3.4.4.2. Mathematics teacher in-service training Project (MATIP)

The serious problem related to mathematics teaching and learning in the black states in R.S.A. has been recognised by the Research Unit for Education Systems Planning at the UOFS in Bloemfontein. After discussions with the authorities in these developing states and after some research it was decided to establish the Mathematics Teacher In-Service Training Project (MATIP) which would concentrate on mathematics for standards 5 to 10. The main components of this scheme are: research, teacher in-service and material production. The main focus therefore is on the teaching of mathematics in the secondary schools. A lot of useful data has already been collected, especially about the teachers, for example Wilkinson (1981) shows the lack of performance in Bophuthatswana schools where the average length of experience is only 3,55 years for std 5 mathe-

matics teachers (P.25). In the same study Wilkinson presents the views of teachers about their students as having a poor grounding in mathematics, they cannot do basic calculations, they dislike mathematics and they have linguistic problems (P.27). In the analysis of pupil's difficulties this author investigated:

i) typical errors made by pupils in the std 5 public exam;

ii) possible influence of the language in which a question paper is set on pupils achievement in the exam;

iii) ability of students in basic fractions and decimals.

These three investigations were done using large samples from the black states - the test on fractions and decimals involved almost 1 200 students. Wilkinson notes the time lag in cognitive development in black children but adds that many researchers question the suitability of Western concept formation tests for inter-cultural studies. It appears that further work is required in this area.

Wilkinson collected empirical data using a large scale sample. While this technique provides big numbers it precludes the deeper exploration of individual students which the clinical method relies upon.

3.4.4.3. Local maths projects

Only two maths projects which might be described as "local" were uncovered, one by Bauer (1984) the other by Murphy (1988). They are summaried here.

(a) Tlhabane miracle maths project

In the Bafokeng region is one College of Education - Tlhabane. There young men and women are prepared for primary (P.T.D.) or for secondary (S.T.D.) teaching. Some reorganisation was needed when the colleges of education in Bophuthatswana discontinued taking std 8 pupils for admission and insisted on a minimum of std 10 pass. With the new courses it was realised that there was an appalling lack of understanding of very basic mathematics and the Tlhabane College designed what it called "Tlhabane's Miracle Mathematics Project" under the guidance of Dr.G. Bauer, lecturer in Career Guidance at the college. This was not a "project" in the sense of experimental design but consisted of a series of work cards and self test sheets designed to build up competence in the use of fractions, decimals and percentages among the first year P.T.D. students and it ran for the first two semesters of 1984. Its motto was "confidence through competence" and its method was to have the students work through a lot of drills graded from easy to hard. The staff were fairly sure about the good results of the project but for some reason or other the project has not continued.

(b) Lebowa oral mathematics project

The director of this project had experienced the problems his students had with basic arithmetic while working in Lebowa middle schools 1986/87. He came to realise the poor performance of the students was related to weak teaching styles in black classrooms and decided to try to design and implement a radically different approach which he outlines in the February issue of Educamus 1988. The project was two days of oral arithmetic in a private school for girls in Lebowa in March 1987. There was lots of group work, outdoor movement and immediate rewards. The tasks to be mastered included such operations as: (a) multiply and divide by 10, by 100, by 1 000 including decimal examples; (b) multiplication tables 3 to 12; (c) adding and subtracting with the aid of diagrams such fractions as halves, quarters and three quarters; (d) commercial operations applying the skills gained in the other parts. Groups of three were organised. Each had a leader who had a progress card on which tasks could be ticked off by the teachers as soon as they were completed by all the group members. The tasks were written on A4 paper and mounted outside on gables, walls, windows and doors. The input by the director was very short: during about five minutes "class period" he stated the objective very clearly to the entire class and gave examples where needed. The children displayed great enthusiasm, caused

no doubt by the novelty and freedom to move about and talk with friends.

Pre-test and post-test scores were analysed and showed a 25% gain but Murphy considers this to be the least important of the outcomes. Students had experienced success in mathematics - some for the first time in their lives - as a result they now had a more positive attitude to maths which revealed itself in more willing participation in regular class work either by asking more questions, or by volunteering to explain difficult concepts to their fellow students who had problems (Educamus Feb. 1988).

Bauer and Murphy both showed considerable improvements in arithmetic calculations (measured by speed and accuracy) could be achieved by use of drills. The experience of success gained by graded exercises (Bauer) and the added stimulus of working in small groups (Murphy) provided the momentum for continuing with the drills until students achieved mastery. Class visits and observation of maths lessons being taught in the schools were included in the present research to see if any of these features occur and findings are given in Chapter 8.

3.4.5. Determinants of school achievement in developing countries

In the preceding sections the relationship between math-

ematics and culture, some mathematics projects and the state of mathematics research in South Africa have been touched on, but there is a considerable body of educational research in developing countries . . is not rooted in psychology or pedagogy. Schiefelbein and Simmons (1978) have carried out a review of twenty-six studies on the determinants of student cognitive achievement in developing countries for the World Bank organisation using an approach which combines several features:

1) using national surveys to gather data about a wide range of possible influences on learning including extra-school influences;

2) using multivariate or "systems" analysis to sort out the relative importance of a number of the possible "determinants";

3) applying the concept, taken from economics, of the "production function".

Research of this sort has been carried out in South Africa by Verwey who has done national manpower surveys for several of the black independent states (Verwey 1978, 1981). Other workers associated with R.U.E.P. in U.O.F.S. like Nyikana (1982) and Mdlula (1980) have also used this general approach but without the detailed statistical analysis of Verwey or Schiefelbein and Simmons. A major question faced by the research reviewed by these latter authors is why some children

learn more in school than others, and this is very closely linked to the title of the present research. Their findings helped to shed light on success and failure in Bophuthatswana schools.

The authors grouped the possible determinants of student achievement into three categories: school resources and processes, teacher attributes and student traits (Schiefelbein & Simmons 1978, P.9). Student achievement was measured by both statistical estimations and classroom learning (ibid). The 26 studies are 5 from Africa, 6 from Asia and 15 from Latin America.

The findings of the survey were as follows:

A) School resources and processes: Variables identified were: class size; availability of textbooks; homework; and expenditure per student. In 9 of the 14 studies relating the effects of class size to student achievement, larger class size was associated with higher performance or did not affect it. Of 10 studies looking at the availability of textbooks and student achievement, only 7 demonstrated a positive relationship. This is explained by postulating poorly designed textbooks or suggesting that oral or blackboard presentation of the information being tested is sufficient and textbooks are not needed. In 6 of the 8 studies which investigated homework effect on achievement there were significant findings - students who do homework do better in school. Higher expenditure per

student was found by 5 out of 8 studies on this variable not to be associated with higher student achievement.

B) Teacher characteristics: Variables identified were: teacher certification; experience; and training. In 19 out of 32 studies, teachers without certificates had students who performed as well as those who had certificates. Only 7 of 19 studies indicated that years of teacher experience is a significant determinant of achievement. Lastly more years of training is not related to higher student achievement in 5 out of 6 studies.

C) Student traits: Variables here are: SES; health; repetition; and kindergarten attendance. As expected, 47 cases studied show significant relations while only 17 studies showed no impact or a negative one. Out of 13 studies on SES, 10 found it a significant predictor of achievement. SES is usually a composite of parents' occupation, incomes and education. Health is a significant factor in 8 out of 11 cases, it being highly correlated with SES.

Repetition of classes showed the more repeating the student did the lower his score in 7 out of 8 observations. Only 4 observations about kindergarten attendance were made and 3 showed it had a significant impact on achievement.

The variables identified by Schiefelbein and Simmons, Verwey and others provide a sound basis for the present

research. The variables can be grouped under (i) Home variables such as socio economic status and degree of westernization of the home (ii) School variables such as furniture, equipment, pupil-teacher ratio, teaching style et.c. and (iii) Personal variables such as age, sex, self-concept, homework patterns, grade repetition et.c. All of these were investigated to find out if they are significantly correlated to performance in maths.

3.5. What emerges from the Literature

From the review of the psychological movements in 3.2. above we see that for successful learning a child must integrate new knowledge into already existing schemata. Second order concepts can only be formed from existing first order ones. Levels of abstraction are progressive in the sense that one must proceed from familiarisation with concrete objects to more abstract levels involving computation, measurement et.c., and if someone skipped out a lower level then it is unlikely that that person could master that particular branch of mathematics in any meaningful manner.

The four basic operations of arithmetic are fundamental and yet it appears a lot of secondary school children are unable to do successful computations and a great deal more are unsure of their meaning and are unable to select the correct operation when faced with a simple word problem. Even more basic than the operations is

the ability to count. The research has shown that counting is no easy task and it may take several years for a child to master even simple whole numbers up to 9. The ordinal and cardinal aspects of number and the relationships between them enable us to gain some insight into the difficulties faced by children at this very elementary stage. The proper understanding of scales and the difficulties children have, even at 12 years, in reading number lines not marked in single units seems to point to lack of adequate counting skills. No research about Tswana children's ability in these areas has been found by this researcher.

Furthermore in more advanced use of the four basic arithmetic operations several strategies have been identified, for example in the case of addition it may be simple counting of two sets consecutively at an early stage and build up to more complicated strategy of recalled or derived number bonds at a higher level of abstraction. We know nothing of the strategies employed by Tswana students. The literature strongly condemns as being counterproductive the teaching of an advanced strategy not based on intuitive methods not used by the students. This may sometimes be thought of as keeping up high standards but it should rather be recognised as wrongly forcing the pace beyond the child's readiness. Teachers in black schools claim they have no option but to teach algorithms whether the children are ready or

not, given the overcrowded syllabus and the threat of public examinations at the end of standard 4, standard 7 as well as matric at the end of standard 10. This kind of teaching may be a root cause of the problems encountered by students in high school who must now adopt a personal style in mathematics whereas their former experiences in the subject encouraged rote learning, without sufficient emphasis on understanding. The following quotation from Hart (1981) refers to poor mathematics achievers:

> ... a child cannot assimilate the type of mathematics which is essentially abstract until he is ready - he must have an adequate knowledge base and build on that ... a child who has been taught a rule for which he is not ready cannot use it in new situations and he will experience failure repeatedly and become discouraged. After a history of failure at decimals or fractions it is little wonder that the next teaching of it in the secondary school is greeted with dismay (ibid P.217).

To summarise:

1. Problem There seems to be a universal problem associated with mathematics in the secondary school (i.e. middle and high school for Bophuthatswana) and in developing countries the problem is aggravated by rote learning and memorisation.

2. Research method The clinical interview method as developed by Piaget and adapted by many other researchers would appear to be most suited ot the purposes of this research. The interviewer's role is that of observer and interpreter of a contrived and planned situa-

tion and he is to be in no way directive. Ginsburg (1983) says a still more objective protocol is to invite the subjects to talk aloud as they work through a problem. Sometimes the interviewer used materials and observed the child's manipulation of them as well as listening to their talk; other interviewers used only paper and pencil material.

3. Mathematics model In most cases, especially the mathematics projects, the only model assumed was that of an external body of knowledge and computation skills which had to be mastered by the child. Some of the other works regarded mathematics as a tool for dealing with the world situation in which the child found himself. It seems to be important to find out what teachers and students in Bophuthatswana think mathematics is.

4. Theories The pyschometric theories were considered to be unsuitable because of their over-emphasis on quantification. Dewey has ideas about democracy and self-development which might be usable in black schools for social reorganisation. Piaget's developmental stages of cognitive abilities were seen to stimulate a lot of the recent research into school mathematics but much of his work is too abstruse for this research. Skemp has described intelligence as a goal-directed process and he has included the whole person, and not just his "brain" in the learning process. Much of his

work on learning of concepts, abstraction, interiority, distractor effects which he calls "noise" et.c. sheds light on the Tswana understanding of mathematics. His discussion of instrumental as opposed to relational understanding seems to apply here. However it is not possible to test whether or not Skemp's theory described in terms of a director system might apply to the Tswana because not enough work has yet been done on how these children learn mathematics nor what are their preferred modes of thinking. Witkin's theory of personality based on field dependence/independence seems to have been well and truly laid low by the severe criticism of its cultural bias and it was noted much of this criticism came from African studies. Nevertheless this method of explaining individual differences in terms of cognitive style seems to be an avenue well worth exploring. Have the Tswana people a style which may be described as a preferred mode of thinking which is based in and fostered by the culture? This could be investigated in such areas as language, sense modality, perception et.c. Is mathematics as taught in our schools based on a western mode i.e. in an analytical manner suitable perhaps for field independent people but unsuitable for field dependent ones?

5. Focus We don't know enough about Tswana children to ask questions about success or failure in mathematics directly in terms derived from the theories presented in

section 3.2. But the kind of school based research reported in section 3.3. of this chapter suggests a possible line of approach. The focus of this study must be the child doing mathematics. The study must seek to know more about the child by looking first at his home, his parents, the physical condition in which he lives as well as his beliefs and what he values in life. Then the school must be investigated and described. Finally some personal characteristics such as listed in section 3.4. above must be investigated to find possible relationships between them and success in mathematics. Generally the focus in the empirical research is on failure and the investigators are concerned with difficulties experienced by children. There is considerably less attention given to why some children succeed in mathematics. It is possible that a study of Tswana children of average and above average performance in mathematics might reveal strengths (or indeed weaknesses!) in how they handle simple arithmetic word problems.

CHAPTER 4

PILOT STUDY

4.1. Introduction

The pilot study presented in this chapter was conducted in 1986 after a considerable amount of reading of literature related to the topic being studied had been done but it was obvious to this researcher that the review of related literature was far from complete at that time. The material surveyed up to then had pointed to a correlational type of research design which would seek to identify factors which were related in a statistically significant manner to success in mathematics among Tswana students. The findings of the pilot study strongly influenced the later work on review of the literature and changed the structure of that chapter and also the research design of the main research. It became clear during the pilot study that a correlational research design would be likely to shed little light on the real nature of the problem, and as a result of this an anthropological design was adopted as described in chapter 5.

4.2. Initial investigation

It is clear from the review of literature presented in chapter 3 that there is a great deal of research into

the learning of mathematics from the standpoint of educational psychology. It is also clear that most of this material comes from American and European sources. But from the limited research that has been carried out in non-technological societies many doubts arise about the applicability of this first-world research to the third-world situation. Schiefelbein and Simmons (1978) have summarised a number of studies on factors related with cognitive achievement in third-world schools and surprisingly they found the following were not significantly related to student achievement:

class size
availability of textbooks
higher expenditure per student
years of teaching experience
teacher certification
training of teachers (ibid P.10 - 12).

The following factors were found to be significant:

amount of homework done
socio-economic status including
parents' occupation
income
education and health of the students (ibid).

It was decided not to replicate these studies but to follow the methodology and use correlational techniques to try to identify other factors which might be statistically significant in relation to student achievement.

The sources explored for these factors were:

(i) personal observation - the present researcher has been teaching mathematics in Phokeng for more than 10 years and has been grappling with the problem of success and failure in mathematics among the Tswana students, both in his capacity as mathematics teacher and educational researcher;

(ii) students - numerous discussions were held with students, both maths students and non-maths students as well as former students who were doing further studies in mathematics at University or teacher's college;

(iii) teachers - many teachers were interviewed, also principals and school inspectors, 23 middle school mathematics teachers, 10 high school mathematics teachers all of whom work in the Tlhabane circuit of education which includes the Bafokeng region;

(iv) literature - specifically South African literature concerned with education in black schools. The Human Sciences Research Council (HSRC) has published quite a number of reports dealing with this issue and the Research Unit for Educational Planning of the University of the Orange Free State also has publications of research in this area.

The factors which seemed to recur with sufficient frequency to warrant investigation were:

(a) attitudes - "most of the Tswana people think mathe-

matics is difficult" "they are afraid of doing mathematics" "they do badly in mathematics because of their attitude;" (interviews and RUEP)

(b) degree of westernization - "if a student comes from a very traditional family background where belief in the badimo (=ancestor-spirits) and muti (=herbal medicine) is strong, he or she won't do well in mathematics;" (interviews and HSRC)

(c) language - "the medium of instruction is English and most students are not able to follow English properly" "they speak only Setswana at home" - "if they know English well they could do much better in mathematics;" (interviews and HSRC)

(d) perception - "many students don't understand simple drawings and figures" "they do not perceive in a diagram what the teacher wants them to see;" (interviews)

(e) self-image - "students easily become discouraged when they fail mathematics' tests" "they lack confidence in their ability to do mathematics" - "they think they are useless in mathematics and that is why they fail." (interviews and MATIP)

Five null hypotheses were formulated on the basis of the above:

There will be no statistically significant correlation between:

1) student attitudes and success in mathematics,

2) degree of westernization and success in mathematics,

3) English language ability and success in mathematics,

4) students' gestalt perception and success in mathematics,

5) students' self-image and success in mathematics

among standard 7 students in the Bafokeng region of Bophuthatswana.

4.3. Research design for the pilot study

Dependent variable: success in mathematics among standard 7 students in the Bafokeng region of Bophuthatswana. "success in mathematics" was discussed in chapter 2.

Independent variables: attitudes, degree of westernization etc as above

Extraneous variables: age, sex, school, mathematics teacher, general school ability were controlled by matching as described below.

Measuring instruments: these consisted of questionnaires, written paragraphs, paper and pencil tests and interviews and are described below in sections 4.5. to 4.9. Each student was interviewed personally by the researcher in order to provide qualitative data that could be used to establish reliability for the written tests. Twenty-six interviews were done, each lasting about 15 minutes.

The sample was composed of four matched groups and selected in the following manner:
two groups of boys: successful and unsuccessful, and two groups of girls: successful and unsuccessful, in mathematics in the standard 7 examination. The criteria for success were: the student obtained symbol E (i.e. 40% to 49%) or better in the standard 7 examination in November 1985 and the student is continuing to study mathematics in high school. The variables used for matching were: age, sex, school attended in standard 7; symbol obtained in standard 7 public examination in November 1985. The original sample of 32 was made up of four groups of eight, in all 16 boys and 16 girls. However some of the girls dropped out of school before the pilot study was completed and data for only 10 girls was used. Once the matching had been completed as described then the marks obtained in mathematics were taken from the school records. A summary is given in Table 4.1.
A computerised analysis of the scored responses in each instrument was plotted against the mathematics mark obtained. The Pearson correlation coefficient was calculated to test the statistical significance of each hypothesis separately. In general the purpose of the pilot study was to help to focus the research design and to indicate what avenues were worth exploring further.
In particular the aims were:
(i) To test the design of the measuring instuments for

clarity of instructions, wording of questions, presentation of material, time required, validity and reliability.

(ii) To provide guidelines for analysis of data.

(iii) To identify important areas which might help to typify successful as compared with unsuccessful mathematics students.

(iv) To explore triangulation techniques for verification of data.

(v) To identify possible procedural difficulties.

Table 4.1. Mathematics attainment mark

	BOYS		GIRLS	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5*	5
Total Score	392	232	225	165
Mean Score	49%	29%	45%	33%
s.d.	5,2	7,4	0*	4,5

*Each of these 5 girls were awarded a symbol E (mark range 40 - 49). For this table each was assigned a mark of 45%. Hence s.d. is 0.

4.4. Procedure

The pilot study was carried out in April, 1986. All the students were gathered together in one classroom and all

received the same instructions. All the tests were done on the same day with a short break after each test.

The personal interviews were conducted the following week by this researcher in English.

Before distributing the test questions brief instructions were given about how to fill in the answers. Pupils were encouraged to be open in their replies and were assured of confidentiality. By way of explanation they were told that their responses could help us teachers to understand the problems the students had in mathematics and maybe help their companions to do better in mathematics in the future. As they were waiting for the first questionnaire they were given some sweets to help put them at ease. In spite of this there was an air of tension and nervousness as shown by a hushed silence unusual for a group of students in Bafokeng High School. They seemed to have some trouble getting started with the first test which was the open questions on attitudes and over half of them took longer than 30 minutes to complete this first page. However nobody asked for help or said he or she did not understand a word or sentence on the paper. There were very few ommissions to any of the questions. Four students did not answer the question asking about the qualities of a good maths teacher, otherwise all the students answered all the questions.

4.5. Attitudes

Two instruments were designed to test the first hypothesis that there would be no statistically significant correlation between success in mathematics and attitudes of students towards mathematics. One of these consisted of seven open-ended questions and the other consisted of 28 closed questions. The students spent a lot of time at the open-ended questions, most took over half an hour to complete it, but they went through the closed questions very quickly and had finished all 28 questions in just over 5 minutes.

4.5.1 Closed questions on attitudes

This instrument was made up of 28 statements which the students were asked to answer by ticking one of the headings:

(i) Yes, I agree

(ii) I don't know

(iii) No, I disagree,

for each statement. The selection of statements was based on Husén (1967) International study on achievement in mathematics and adapted for Bophuthatswana by this researcher. A pre-test consisting of 40 questions had been administered to the standard 10 mathematics class in Bafokeng High School in November 1985 and as a result 12 questions which proved ambiguous were dropped. In the pre-test a 5 point scale was used and this was

changed to the present 3 point scale because the other proved cumbersome. The scoring was +1 for a positive response; 0 for neutral response; -1 for negative response. The decision about what constituted a positive or negative response was made after discussion with two colleagues in the mathematics department of Bafokeng High School to increase both reliability and validity. No agreement could be reached by the markers concerning Q.17 and Q.21 and these were omitted from the scoring. Hence the scores could range from a maximum of +26 (positive attitude) to a minimum of -26 (negative attitude). Marker agreement on items used was then 100%. The boys' and girls' scores obtained in this test are given in Table 4.2.

Table 4.2. Scores obtained in attitudes questionnaire

	B O Y S		G I R L S	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5	5
Total Score	+134	+45	+96	+39
Mean Score	+16,8	+5,6	+19,2	+7,8
s.d.	+2,4	+3,7	+2,2	+5,1

It can be seen from Table 4.2. that the successful students, both boys and girls have strongly positive at-

titudes towards mathematics as measured on this instrument. The unsuccessful boys and girls are much less positive in their scores.

The Pearson correlation coefficient for attitudes to mathematics against mathematic's attainment mark = 0,578 ($p < 0,01$)

Care must be exercised in interpreting the results because these students had already experienced failure in mathematics in the standard 7 public examination and further they had already made the decision not to pursue mathematics in high school. The sample is too small to allow for generalisations to be made but the results do indicate that this instrument can provide information concerning successful students namely that when compared with the unsuccessful ones they have a more positive attitude towards mathematics. It was decided to keep this instrument for the large scale field work but to build in a consistency of response factor by repeating one question.

4.5.2. Open questions on attitudes

This instrument consisted of 7 open ended questions such as: Why are you doing maths? What qualities do you think a good maths teacher should have? The purpose of this set of questions was to provide alternative evidence which could validate the closed questionnaire using triangulation. To quote Cohen & Manion (1980):

> In its original and literal sense, triangulation is a technique of physical measurement: maritime navigators, military strategists and surveyors, for example, use (or used to use) several locational markers in their endevours to pinpoint a single spot or objective. By analogy, triangular techniques in the social sciences attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint and, in doing so, by making use of both quantitative and qualitative data. (P.208)

The responses on the open questions support the findings from the closed questions. This test shows the two groups of successful students, both boys and girls, to be strongly positive in their attitudes towards mathematics. These students used phrases like "it is easy" ... "I like it" ... "it can help me in my career"... "maths helps me to plan better" ...etc. The group of successful boys are very dynamic in their responses and they are aware of benefits to themselves e.g. "maths helps me in mental development". By comparison the successful girls are much more limited in their view of mathematics and they only mention mathematics as something which can help them in finding a good job or enabling them to avoid subjects like history which they don't like.

The two groups of unsuccessful students, both boys and girls are very negative towards mathematics. They use phrases like ..."it is difficult" ... "I don't like maths" ... "I don't understand maths" ... "I am not interested in it" ... "I hate it" ... etc. Several of

these mention failing in the examination and it is clear this experience of failure has been damaging to their self-image in relation to mathematics. In spite of this 8 of the 13 unsuccessful students say everyone should do mathematics up to standard 10 for the purpose of getting good jobs after school.

Another distinction between successful and unsuccessful students that emerges from their replies to this instrument is what they think about mathematics teachers. In reply to the question about what they think are the qualities of a good mathematics teacher most of the successful ones wish the mathematics teacher to have personal qualities such as ... "good ideas" ... "determination" ... "patience" ... "well organised" ... etc. On the other hand the unsuccessful students mention only professional qualifications like ... "he must be qualified" ... "have a degree" ... "be well trained" ... etc. It must be remembered they are not talking about different teachers because these students were matched for this variable.

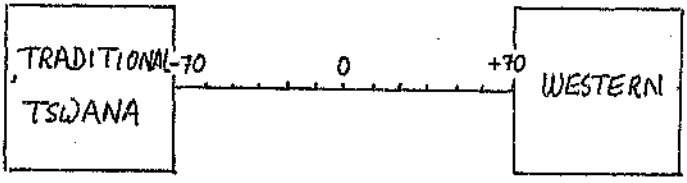
4.6. Degree of westernization

In the literature, especially in H.S.R.C. reports there is great stress on the effect of culture on the performance in mathematics among black people in South Africa (e.g. Groenwald (1976) and Van den Berg (1978) as discussed in Chapter 3, section 3.4.4.1.) Others like Gay

and Cole (1967) in their studies on the Kpelle of Liberia have shown that in a primitive non-technological society, a different type of mathematics from what we normally understand by this term, may be more appropriate for survival, and the Kpelle far out-score their western matched groups in estimating such things as quantity of rice in a given container. They scored highly in problems relevant to themselves and poorly in the more ordinary mathematics. Okonji (1969 and 1971) has done research on the effect of culture on a people's thinking, although in his studies, crude physical environment seems to be the dominating factor and he relates lack of certain necessary nutrients with performance in intellectual tasks. For these reasons it was hypothesised that there could be a correlation between degree of westernization and performance in mathematics. Diagramatically it was assumed traditional Tswana culture and western culture could be quantified and these would represent the two extremes of a continuum as shown in Fig 4.1.

It was expected that the four matched groups of students would be situated at different points along the continuum - those who were good at mathematics were expected to be far to the right, and those who were poor in mathematics were expected to be towards the left.

Figure 4.1. Degree of westernization continuum



McClelland (1975) presents one method of analysing national character and this was used by Kiely (1983) to analyse the Tswana character using the following categories:

a) child rearing
b) political behaviour
c) religion
d) leisure
e) work
f) death
g) general

These seven categories were used to construct the measuring instrument by designing questions in each category to score a maximum of 10 points. To each question two extremes were devised after consultation with 27 staff members of Bafokeng High School. These extremes were scored "-" for the traditional Tswana one and "+" for the western one. The scores therefore could range from a possible -70 which would indicate an ex-

tremely traditional Tswana person, to a possible +70 which would indicate an extremely westernized Tswana person.

The scores obtained are shown in Table 4.3.

Table 4.3. Degree of westernization

	B O Y S		G I R L S	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5	5
Total Score	-27	-28	-32	+25
Mean Score	-3,4	-3,5	-6,4	+5,0

The scores show no significant difference between the two groups of boys but the girls' scores not only showed a very wide divergence of values but were quite the reverse of what had been anticipated.

The Pearson correlation coefficient for degree of westernization against mathematics attainment mark was: boys 0,123 (non significant); girls =-0,648 ($p < 0,01$)

As a result of the pilot study certain items need to be redesigned, others needed to be reworded. Still others yielded no clear information and were omitted.

The instrument itself was judged to differentiate between successful and non successful students, at least in the case of the girls and it was decided to include it in its modified form in the main field study.

4.7. English language ability

According to Dickson et al (1984) there is very little research literature available on the role of language in mathematics learning because interest in this field is a relatively recent development (P.335). Be that as it may there has been considerable interest in, and controversy about, the relationship between language and thought. On the one hand psychologists like Bruner claimed linguistic development precedes abstraction and at the other extreme Piaget considered thought to comprise "internalized actions" and therefore cognitive development comes first. Dickson et al (1984) quote Piaget (1972):

> Linguistic progress is not responsible for logical or operational progress. It is rather the other way round. The logical or operational level is likely to be responsible for a more sophisticated language level.

Despite Dickson et al's claim that little research has been done, Skemp (1971 and 1979) deals with language and mathematics learning. Skemp distinguishes between a concept and its name:

> A concept is an idea, the name of a concept is a sound or a mark on paper associated with it. This association can be formed after the concept has been formed or in the process of forming it. Skemp (1971, P.23)

Dickson et al (1984, P.331) refer to Choat (1974) and Vygotsky (1962) who appear to agree with Skemp's position that thought and language, while not to be confused

with each other are nonetheless interdependent.

Gay and Cole (1967) put forward the extra problems introduced by language in the teaching of mathematics when they showed that some languages don't have names for certain necessary mathematical concepts. Bishop (1983) reports the same difficulty:

> language is a confounding variable. In a place like Papua New Guinea it is difficult to separate conceptual limitations from linguistic confusion, (Bishop 1983, P.195)

Bishop goes on to discuss the problems that arise in teaching mathematics in less technologically oriented cultures. He notes that home life culture tends to be socially oriented and school culture more abstract and analytical.

Serpell (1976) quotes Ferguson (1959) as defining High and Low language according to aspects of culture normally discussed in each language. Home life is generally thought of as low culture, school life is regarded as high culture. Siann and Uguegbu (1980) found the same to be true elsewhere and they quote the work of Young (1977) who researched attitudes of educated Papua New Guineans towards "village" knowledge and school knowledge. As a whole, Young's subjects were favourably disposed to the type of knowledge that they thought was typically taught in schools (Siann and Ugwuegbu 1980, P.209). The cultural conflict that arises is described by these authors thus:

> Within Western frames of cognition, when a problem is put, say, in a school situation, ... the subject is assumed to be aware that in answering that problem he must confine himself only to what is given in the problem. He must not venture outside the problem set by reference to any specific knowledge he may have about what happens when that type of problem occurs in everyday life. Instead he must "disembe... the problem (ibid P.206).

A fuller discussion of language and mathe... will be presented later in Chapter 7 when the issue of bilingual teaching will be dealt with.

In order to examine the relationship between language and mathematics attainment Skemp's definition of language was used. Skemp defines language as:

> A set of symbols with their associated cor... such that for certain relations between the s... there corresponds certain relations between the ...cepts. In a verbal language the relations bet... symbols include order of words, punctuation, and inflections. So the concept "meaning of a word" can now be expanded to "meaning of an ordered and punctuated group of words and their inflections" (Skemp 1979, P.159).

Two tests were used to measure English language ability, one a dictation exercise which depends largely on the ability to hear and comprehend spoken English and the other a written comprehension passage which tested the ability to read and comprehend. Many authors distinguish between reading skills and comrehension of content (e.g. Minkowich et al 1982, and Watson 1980) but it was decided that for the purposes of this study it would be sufficient to compare oral and written understanding and to examine the relationship between each of these and mathematics attainment.

Michau (1978) has reviewed some of the research into the connection between language and maths achievement among Zulu students and she has identified two crucial areas, viz the effects of culture and the effects of language on the development of mathematical proficiency (Michau 1978, P.21).

4.7.1. Dictation

All of the mathematics teaching in the Bafokeng region of Bophuthatswana is done through the medium of English, and in most cases the teacher talks, using the lecture method. The passage chosen for dictation was a paragraph from a standard 7 career guidance book. The test took just over five minutes, the students seemed to find it very easy and the scores were generally high as seen from Table 4.4.

Table 4.4. Scores on dictation test

	BOYS		GIRLS	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5	5
Total Score	242	236	164	161
Mean Score	30,3	29,5	32,8	32,2

The passage was read by the researcher slowly in short phrases and was repeated just once. The scoring was done on the basis of Skemp's definition of language quoted above. From a maximum score of 40 there was deducted one point each for mistakes in:

(i) punctuation and spelling

(ii) order of words and

(iii) meaning of each sentence

The results show there is no statistically significant correlation between dictation and mathematics attainment. Pearson correlation coefficient = +0,116 (N.S.)

4.7.2. Reading comprehension

The comprehension test was one chosen by the senior English teacher in Bafokeng High School from the text book used by the standard 8 students. The scoring given in the text book was used without alteration. Maximum score was 40 points. During the administration of this test all the 26 students obviously understood the task, and they took an average of 10 to 15 minutes to read the passage, then they set about answering the questions, constantly referring back to the passage to find the answers. One student finished in 30 minutes, three took 40 minutes five took 45 minutes and most of the others required a full hour to finish.The passage was typed on A4 paper and each student received a copy of the passage

together with the questions.

The scores were as shown in the Table 4.5.

Table 4.5. Scores on the comprehension test

	B O Y S		G I R L S	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5	5
Total Score	191	156	66	95
Mean Score	23,9	19,5	13,5	19,0

The results here show no clear pattern. For the boys those who were successful scored higher, on average than those unsuccessful in maths but the opposite was true for the girls. There is a very small non-significant negative correlation -0,017 (N.S.) between maths mark and comprehension scores.

4.7.3. Result

It was decided that language and mathematics learning probably does need investigation but that the dictation and comprehension tests used here yielded no useful information and would not be used in the main field study. A number of small scale language tests would be designed instead along the lines suggested by Michau (1978),

Bishop (1983), Gay and Cole (1967) and focus on the Tswana language itself.

There is no need to give a separate comprehension test as the marks obtained by the students in the standard 7 public examination could be used to establish possible correlations between maths and English attainment marks.

4.8. Perception

The recognition of patterns and the ability to copy them as in the Koh's blocks test has been used for many years in intelligence tests. At the Bafokeng platinum mines training centre one of the test batteries used to select candidates for further training from among new, mostly illiterate recruits is just such a test. The embedded figures test is also used to measure analytical ability in the sense of being able to break down a complex figure into its simpler components. Serpell notes the similarity between the Koh's block test and the EFT (Serpell 1976, P.39) since both depend on visual perception. It has been observed that one feature which distinguishes "western man" from "African man" is that the preferred mode of communication for the former is visual at least in the present age, whereas for the latter oral communication and body language has up to now remained the dominant mode of communication.

In 1960 Hudson sparked off an avalanche of research by his article on pictorial depth perception in sub-

cultural groups in Africa. His findings were challenged by Dawson (1963 and 1967), Wober (1966 and 1967), Okonji (1969), Berry (1968) and Deregowski (1968 and 1972). The outcome of all this research was a deepening of our understanding of pictorial perception and the role of schooling. It was found that perception of, for example depth or again, movement, in a picture depended on a number of visual cues which were learned by exposure to pictures. Serpell quotes Miller (1973):

> If an individual has never learned that a picture may represent some object he will not be able to perceive any object when first presented with a picture (Serpell 1976, P.99)

Verster (1982) found white males scored higher than black males in the area of video-spatial thinking. The research was done in R.S.A. and use was made of tasks involving perceptual disembedding of a figure from a ground (P.267). Skemp observes that director systems, within a person, have no direct access to actuality, the outside, and depend on mental mode's which are activated by sensory input among other things. In perception inner reality and actuality fuse into a combined experience in which each is modified by the other. He defines perception as "becoming aware" (Skemp 1979, P.32). Elsewhere Skemp discusses how needs etc. may selectively sensitize one's perception (ibid P.139)
From the discussion presented here it seems people differ in visual perception according to their upbringing

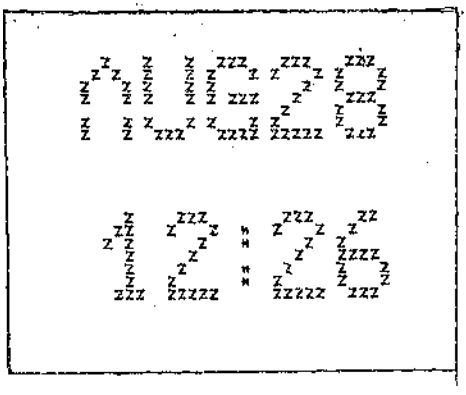
and training. The question must be asked whether there is a link between perceptual style and mathematics attainment. Certainly Witkin claims there is a strong correlation between field independent score and mathematics ability (Witkin 1954).

This researcher has had many experiences both within and without the classroom where the lack of ability to perceive correctly a relatively simple picture or diagram has been a real stumbling block for Tswana students. The whole teaching of science is based on diagrams in many black schools due to lack of science equipment and one wonders at the difficulty faced by secondary school students who must learn electricity from circuit diagrams etc. To recount just one instance from personal experience:

> Elliot M. is the head student in Bafokeng High School. He is studying maths and science. He also helps to organise educational outings for his class. One day he accompanied his maths/science teacher to Rustenburg to hire a bus for the outing. First they had to go to the bank to have the school cheque endorsed. When they arrived at the parking lot the teacher went to the machine and inserted 15 cents and pressed the button and noted the machine had begun to give out a ticket which had date, month and time printed on it using small "z" letters as shown in Fig. 4.2.
> The teacher told Elliot to take the ticket and wait in the car while he himself did the bank business. When everything was completed they drove to the bus depot and finalised arrangements there. On the way back to school Elliot began to laugh and the teacher looking across at him saw he was holding the parking ticket in his hand and shaking with laughter. When asked for an explanation Elliot explained that he had this piece of paper which the parking machine had given out about one hour ago and he had been trying to make sense out of the jumble of "little z letters"

which were on the paper. Just now he recognised their meaning.

Fig. 4.2. Machine printed parking slip



On reflection, this incident seemed to point backwards to the work of Koffka, Kohler and Wertheimer in the early decades of this century in Germany. They were opposed to the analysis of consciousness into elements and they held that a conscious complex experience cannot be constructed from an associative composition of separate elements. They used the word "gestalt" meaning "form and organisation" for the structured meaningful whole which an individual gives from the separate elements (Jordaan & Jordaan 1973, P.16). Their law of perceptual grouping states that the individual is inclined to find the best possible form of figure (= gestalt) so that the Gestalt may aquire the maximum meaning (ibid P.365).

It was hypothesised that the ability to form a gestalt

would be related to mathematics attainment and the experience of Elliot referred to above was used as the instrument. The students were presented with a copy of the parking ticket and asked what they could see. They were given five minutes for the test and were asked to write their answers on a sheet provided. The scoring was done by the researcher.

30 points awarded for - AUG 28 12.26

25 points awarded for - AUG 28

20 points awarded for - Month and numbers

15 points awarded for - Big letters made with small a letter

10 points awarded for - letter z only

The results are given in Table 4.6.

Table 4.6. Scores on the perception test

	BOYS		GIRLS	
	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL
N	8	8	5	5
Total Score	159	154	81	89
Mean Score	19,9	19,3	16,2	17,8

There is some difference between the mean scores of the girls compared with the boys but no significant dif-

ference between the successful and the unsuccessful groups. There is no statistically significant correlation between maths scores and perception scores. The Pearson correlation coefficient is 0.08 (N.S.). As a result of the pilot study it was decided to pursue this line of enquiry on a small scale basis but not to use it for the main field study. Two follow up studies would be undertaken:

(i) embedded figures test and

(ii) the concept of rectangularity among the Tswanas.

4.9. Self image

4.9.1. Literature background

Terminology in the literature can be confusing in relation to this topic of "self". Authors use terms such as "self-concept", "self-esteem", "self-image" and "attitude to self". Here no distinctions will be made and the term used will simply indicate the view that the individual has of himself as an individual (Jordaan & Jordaan, 1975 P.32). In the following discussion use will be made of the working definition presented by Siann and Ugwuegbu (1980) who say:

> ...self may be defined as the knowledge we all have of ourselves that embraces our past history, our present existence and our expectations of our future life .... (ibid P.71).

Another difficulty which arises concerning self-image is how to measure it, the most popular being an instrument

which is a questionnaire composed of a large number of questions scored on some form of Likert scale. One such instrument was constructed for use in Bophuthatswana schools by Kiely (1983, P.224) which consisted of 60 questions and used a 5 point Likert scale. Slann and Ugwuegbu (1980) address this issue of how to measure self-image and they report from their study of empirical research that the best predictor about how people would behave under certain circumstances was:

> ...simply asking subjects themselves how they thought they would behave. In other words, insight into other people can be gained by asking them how they view themselves (ibid P.71).

For these reasons it was decided to collect qualitative data only in this section and two instruments were used:

(i) personal interviews, carried out and recorded by the researcher and

(ii) written paragraphs entitled 'myself' written by each student in the form of a letter to the researcher.

During the interviews, each of which took approx 15 minutes the researcher focussed on:

(a) general impression based on: dress, facial expression, gestures, language ability in English which included the ability to understand the question asked as well as to reply in an intelligible manner;

(b) answers to specific questions clustered around

(i) student himself

(ii) parents and home

(iii) friends

(iv) school and mathematics

(v) plans for the future.

4.9.2. Results and findings of self image questions

Firstly regarding (a) general impression, the group of successful boys cannot be differentiated from the group of unsuccessful boys on this basis. All of the boys were found to be very friendly, responsible, thoughtful in their replies and very pleasant to talk with. Only three of the total of 16 boys interviewed could be said to be poor in speaking English and two others were a bit frightened by the interview ordeal. One boy (from the successful group) positively resisted being questioned and had to be literally "captured" by his companions having eluded the researcher's attempts to interview him - he said bluntly that he did not believe this interview was for research purposes but refused to say what he thought its purpose was. He was "released" without further pressure to answer.

Similarly there were no clear differences between the successful and unsuccessful girls emerging from this part of the interview. Two of the ten girls (one from each group) were shy and had very limited English; otherwise they seemed to be well-mannered, hard working and friendly and they tried at all times to answer in an

open straightforward manner.

Secondly in their answers to (b) (the specific questions part of the interview) there was little to distinguish the successful from the unsuccessful students. Some slight differences did emerge and they are given in the appropriate section below.

(i) Students themselves - during weekends most of the boys spend their time working around the house, playing soccer, studying, going to church, talking with friends, watching TV or engaged in other forms of relaxation. More of the successful boys mentioned work around the house and study than the unsuccessful ones who mentioned playing soccer more often. The same pattern was noted with the girls - the group of successful girls spend more time at home working around the house and going to church on Sunday and by comparison the group of unsuccessful girls indicated more varied occupations and past-times. It was clear from their school uniforms and shoes that all the students interviewed were from a fairly low socio-economic background. This was confirmed by their answers to "How would you spend R100 ?". Most said they would buy food, groceries, candles or other items required at home or else they would buy school clothes, shoes or textbooks. Just one or two in the group said they would use the money to buy new fashionable clothes for themselves and only one person out of the 26 interviewed said he would spend it in Sun

City. Only four of the 26 have electricity in their homes.

(ii) In their replies all the students showed a great love and respect for their parents and even those who had to work hard at home and those who were very poor expressed real pride in their family. Ten of the 26 have their fathers working in Johannesburg - the others work locally and live at home. Three of the 26 have their mothers also working in Johannesburg and 10 of the 26 have their mothers working locally. Two of the 8 successful boys say their mothers are not married. It also appears the parents of the unsuccessful boys are better educated than those of the successful boys which seems strange. The opposite is the case for the girls - 2 of the 5 successful girls have parents who completed standard 10, but none of the unsuccessful girls' parents did standard 10. Three of the 8 successful boys say their families don't have any newspaper coming regularly into the house. All the students have some kind of radio and 17 say they listen most often to Radio Tswana while only 9 say they prefer Radio Bop. Over half of the 26 students say corporal punishment is used at home when they do something wrong, including many of the girls, although mostly the girls said they are scolded rather than beaten for wrong behaviour.

(iii) When talking about friends an interesting point emerged. The groups of successful students seemed to

spend more time at their school work than with their friends while the opposite was the case with the unsuccessful students who seemed to be more sociable. Three out of the successful boys and 2 of the girls said they didn't have any special friends because the didn't trust other people and they may lead them into trouble. It appears the successful mathematics students are characterised as a conservative group, very highly motivated to success in school, and a bit fearful of being led astray by companions. These characteristics are generally the result of home life and the urgings of parents for their children to do well at school. This parental pressure also emerged from the replies about punishment. Six out of 8 successful boys said they were beaten and their parents used corporal punishment for wrong doing as compared to 4 out of the unsuccessful boys.

(iv) Nothing very clear arose from this part of the interviews to distinguish successful from unsuccessful students. All the students attend school so that they can get good jobs and have a good future. All said they liked school. Most of the unsuccessful girls mention helping other people as a reason for choosing a certain career. In answer to the question: "Why do some students do well in mathematics and others do badly?" there was no pattern which could be identified.

(v) Regarding their plans for the future there is a

clear distinction between the groups. The two groups of successful students - both boys and girls - prefer science-orientated and technical careers like engineering and medicine, whereas the unsuccessful boys and girls prefer more social-type careers like teaching, law, and social work.

4.9.3. "Tell me about yourself" letters

The purpose of this instrument was to complement the interview. The student was given a page which had written at the top:

> I don't know you please tell me about yourself. Write a short paragraph here about yourself.

This instrument was based on Jersild (1952) who used unstructured compositions to explore self-conceptualizations. Jersild categorized the responses into fourteen groups such as: physical appearance, ability in sports, personal character, social attitudes, parents etc. (Gordon, 1975 P.264).

There are very clear differences between the boys and the girls in their letters about themselves as one would expect from Tswana children, where the culture still distinguishes very sharply men's roles from women's roles. For example the boys are more concerned about physical characteristics, personal character and human relations. The girls are much more limited in what they have to say and speak mostly about school subjects,

their homes and future careers.

In comparing the matched groups of boys i.e. the successful against the unsuccessful it appears the latter are more out-going and they list more activities such as playing soccer, visiting friends, making jokes. The successful boys are more concerned about school subjects and the difficulties they have in school. The same is true for the girls and the unsuccessful ones are more sociable than the successful ones.

In general the letters confirmed what had been emerging out of the interviews namely that there are personality differences between the two groups - the successful students are hard working and dedicated to their school work under the influence of fairly strict parental control. The unsuccessful students are more sociable and out-going and are interested in subjects like history and literature.

4.9.4. Results of self-image investigation

No quantification of data was attempted here but the findings do indeed indicate a strong correlation between self-image and achievement. It was decided to use the self-image variable in the main study but to revise the instruments in the light of the work of Minkowich et al(1982). This would facilitate a quantification of data for this variable. At the same time qualitative data could be collected in a shorter form during the

personal interview which would focus more specifically on mathematics and the student's own perception of himself in relation to mathematics.

4.10. Findings and conclusion

Not much useable data were collected from the pilot study and t[illegible] reasons may be listed as (i) small sample of 26 (ii) main purpose of the study was to test the measuring instruments not to collect data (iii) the rigid "over-objective" approach of the researcher which was a move away from anthropological to so-called scientific research (which has proved inadequate to deal with the real nature of the problem of success and failure in mathematics) (iv) the criteria for "success" had to be lowered to such an extent that it is doubtful if any of the successful group were properly belonging to that category at all. The reason for this lowering of the criteria was to enable the researcher to make up sufficient numbers for matching purposes. The first draft of the pilot study was written up in the form of a "progress report" in October 1986. It was agreed that as it stood using a scientific design, it really did not serve the main purpose of this research. It was agreed that it was necessary to look for insights and that the anthropological approach was more likely to illuminate the real nature of the problem. Hence the researcher pursued the following strategy:

step 1: Return to basics - what is this research about?

step 2: What use is Skemp's model for this research?

step 3: Can any empirical data be collected as a result of step 1 and 2 ?

step 4: Can this data be structured in a meaningful manner?

This research aims to uncover differences between successful and unsuccessful students in the learning of mathematics at standard 7 level. The main criterion for success was performance in the standard 7 public examination. In the pilot study only 4 students scoring symbol D (50 - 59%) could be used in the matched groups, the rest of the "successful" students obtained symbol E (40 - 49%). On investigation of the marks sheets for the standard 7 external examination sent to the schools it was discovered that these mathematics marks had been moderated upwards by more than 10% and sometimes by as much as 30% which meant that many of the "successful" group had in fact scored less than 4 % in their real performance. It seems necessary that in view of this finding the criterion for success should be "obtain symbol D or better".

This research has set out to look for differences in preferred modes of thinking that may enable a student to reach that high level of abstraction which is necessary in order to succeed in mathematics - and this does not

include merely to scrape a pass.

Skemp (1979) develops a model of intelligence based on a goal-orientated director system. In his build up to the model in Chapter 1 to 4, Skemp discusses several issues which shed light on the present research. Briefly these are:

(i) By "success" Skemp means the ability to use information in new situations and the ability to think in alternative ways of reaching a goal state. (ibid P.191) This is very different from scoring a mere 40% in a maths examination.

(ii) Skemp discusses the role of emotions in hi overall view of intelligence. Intelligence is the ability to learn and its function is the development of director systems which are adaptable and successful (ibid P.10).

(iii) In his presentation on consciousness, Skemp distinguishes between an "outer world" called actuality and an "inner world" called reality. We direct our actions and experience the result of these actions within the limitations of our own inner realities. The actions themselves and the objects of these actions exist in actuality (ibid P.21).

(iv) The fit of inner reality to outer actuality is carried out by a process Skemp calls reality testing. There are three modes of such reality testing:

mode 1: experiment - testing expectations with facts;

mode 2: social - testing against knowledge and beliefs of other people by discussion;

mode 3: internal consistency (ibid P.34).

Empirical data can indeed be collected as was shown in the pilot study. The instruments on attitudes, degree of westernization, and an adapted form of the self-image were used in the main study. But this was not enough. An effort had to be made to find out how the students think - how they experience within themselves the outer world of actuality and what modes of reality testing they use. For this, a research design based on an anthropological model had to be devised and this will be described in the next chapter. For the structuring and analysis of the data it was decided to use Skemp's model of intelligence as a framework for problem solving procedures. But this model is limited because too little is yet known about Tswana students in the area of learning mathematics. The framework of cognitive styles as developed by Witkin in his field-dependency theories and other authors who have built up other frameworks was also used for analysis of the data of this research because of its flexibility and also because of the amount of research already done in this area by Okonji, Wober and others using African subjects.

CHAPTER 5

RESEARCH DESIGN

5.1. Introduction

As a result of the pilot study described in the previous chapter a major redesigning of this research was necessary. The correlation study proved incapable in this instance of uncovering the real nature of the problem. The field of research being undertaken here is largely unknown territory and a great amount of exploratory work must still be done before the stage of hypothesis testing can be reached. It was decided that a design based on the anthropological model rather than that of the natural sciences was called for and that the uniqueness of the Tswana students must be explored in depth. The purpose of the research design is twofold according to Kerlinger (1986, P.280), to provide answers to research questions and secondly to control variance. This is done by making a plan and by providing a structure (ibid P.279). This may be a straightforward matter in some situations but there is nothing simple about it in the present social structure in the Bafokeng region which is characterised by rapid social change as reported in chapter 1; indeed the changes were evident even as this research was in progress. There has been a population explosion during the past twenty years which coincided with the economic exploitation of platinum; there has been a shift in the occupations of the people

from cattle and crops to mining, factories and wages; tarred roads, dial telephones, television and Sun City are just a few things which have come to the region in the eighties; and just over ten years ago the region was incorporated into the new state of Bophathutswana. In the schools the response to technology has been to heighten the interest of everybody in mathematics because this is perceived as one sure path towards securing an easy well paid job.

Educational research which is carried out in such situations of rapid change presents several difficulties which have been summarised by Serpell (1976):

(i) Regarding theory, the tendency is to apply theories developed in the West and to force them onto the non-western society in order to establish how general these theories are (P.112). Usual' it is found such theories are not applicable and the common explanation is sought in how the theory was operationalised instead of questioning the theory itself. Research must start with the situation and the people in their own culture and not with a theory into which they are forced to fit willy nilly.

(ii) The ethnic bias of the researcher who is an outsider tends to shape the significance and definition of problems and in the African context it must be acknowledged that there does exist a deep seated belief in the myth of Western racial superiority (ibid P.115). Berry

(1969) according to Serpell (1976 P.116) acknowledges this problem as a serious one for the validity of the research. He says the best that can be hoped for is that the researcher may achieve a "derived outsider's view concept" which may be "functionally equivalent" to the "insider's view concept". This may come about only if the researcher is conscious throughout the research of the personal bias arising because of his own culture (ibid).

(iii) The very matter of tests and instruments used to collect data and how to analyse the data is also a problem. The dice are loaded in favour of well established tests naturally, but most of these have been designed in the West. Most researchers are unable to consider radical alternatives because they are unable to see the behaviour they are studying within its own unique cultural context (ibid P.117).

The design presented in the following pages therefore attempts to unravel the question of success and failure among the Tswana students of the Bafokeng region by using participant observation and clinical interviews as the major research tools. The theoretical background is discussed in 5.2. below and the structure is set out in 5.3. The rest of this chapter fills in the details of the plan to control variance.

5.2. Research methodology

5.2.1 General approaches

There are two major approaches in educational research which may be described as normative and interpretive (Cohen and Manion 1980, p.21). The normative approach follows the method used in the natural sciences. Using this method to explain human behaviour requires of the researcher:

> to adopt the perspective of a detached outside observer intent upon classifying what he sees and hears in the light of some theory he holds about the way society is structured... (ibid p.22.).

This approach can be conceptualised in terms of Dewey's analysis of a complete act of thought as outlined in Chapter 3 section 3.2.2. Kerlinger (1986, p.11) uses Dewey's analysis to present his discussion of the scientific approach in behavioural research.

The second one is described by Cohen and Manion (1980, p.23) as "interpretive" and is based on the principle that man has the unique ability of being able to interpret his experiences and represent them to himself. Katz (1953, p.59) pointed out this method of interpretive anthropology has been widely used by anthropologists in conducting field studies. According to Katz there are two types of field studies, exploratory and hypothesis-testing. In the exploratory study the researcher tries to see what is there and then from the findings may come knowledge about important

relationships between variables which later must be tested (ibid P.74). The work of Gay and Cole (1967) and Cole et al (1971) which was discussed in Chapter 3 section 3.4.1. above could be seen as an example of this type of field study. Kerlinger (1986) refers to this type of research as "non-experimental" which he defines as a:

> ... systematic empirical enquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulable. Inferences about relations between variables are made, without direct intervention, from concomitant variation of independent and dependent variables (P.348).

Nisbet (1980) notes the fact that many educational research workers are growing more disillusioned with the results of traditional empirical research and he advocates the anthropological model because it enables the researcher to see the educational process from the viewpoint of the learner. He continues:

> The descriptions used by different participants to explain their experience provides an exploratory tool (P.6).

Ary et al (1985) use the term "research method" as referring to the general strategy followed in gathering and analysing the data necessary for answering the question at hand. These authors list four categories for classifying educational research:

1) experimental, in which variables are manipulated;

2) ex post facto, in which the variables cannot be

directly manipulated;

3) descriptive, which describes and interprets what is present;

4) historical, in which the historian attempts to tell what was (P.26).

Before this section is brought to a close attention must be paid to an important contribution made by Skemp (1982) on this question of methodology. Skemp discusses two categories of theory in relationship to mathematical learning. Type 1 theories are those typical of the natural sciences. A Type 2 theory on the other hand is a model of regularities in the ways by which Type 1 theories are constructed and by which plans of action are derived from these theories. Each of these has its own methodology. Type 2 methodology is concerned with constructing models of how Type 1 theories are constructed. The word "constructed" is explained as the building and testing by one of three modes: (i) experiment (ii) discussion or (iii) internal consistency. Skemp then stresses the importance of this distinction between the two methodologies if one is to avoid the anomaly of building a Type 2 theory but using a Type 1 mode of testing. Mathematics is a Type 1 theory but research aimed at understanding how people learn mathematics is a Type 2 theory (P.183-189).

Skemp then gives the following practical guidelines:

> From the foregoing analysis, diagnostic interviews and teaching experiments both emerge as methods ap-

> propriate for the construction of a Type 2 theory. In a diagnostic interview, the experimenter sets up internal tentative images of what might be in the child's delta-one ... he tries to get inside the child's mind ... the experimenter may hope to construct images of the thinking ... and ... of the ways in which they construct plans from their available schemata. From these, regularities may possibly be abstracted and put together into a theory. (ibid p.189).

Snow (1976) in reviewing research in education for 1976 refers to research which sought to distinguish field independence from general intelligence and then relate it to mathematics achievement but failed to isolate the cognitive style factor. The mathematics score may represent either or both of two abilities or a more basic one, and correlational analysis alone, he claims, will never solve this problem. Snow (1976) like Skemp (1982) calls for process descriptions of how students solve the problems represented in different tests and this calls for introspective interviews as well as much experimental analysis (p.80).

In the light of the above discussion it was decided to construct a research design which could be described as:

(i) anthropological in terms of Nisbet and Cohen and Manion;

(ii) nonexperimental in terms of Kerlinger;

(iii) descriptive in terms of Ary et al;

(iv) field study in terms of Katz;

(v) Type 2 in terms of Skemp.

The research question was: What factors are associated

with success and failure in mathematics among standard 7 students in the Bafokeng region of Bophuthatswana?

The research method used was "illuminative" in character and by this is meant the researcher became immersed in the situation itself,; while maintaining an openness to the total situation yet was tuned into whatever emerged in the investigation; by gradually deepening the study the researcher attempted to zero in on critical areas. Statistical analysis was used as appropriate. Triangulation techniques were used as the basis for checking reliability and validity.

5.2.2. Delimitations

After the initial survey of the literature was carried out it became clear that the field of mathematics education was indeed a very broad one and it would be impossible to pursue all the leads that existed. For example Alexander and Simmons (1975) and Schiefelbein and Simmons (1978) have reviewed determinants of school attainment research in developing countries and the number of variables investigated runs to more than fifty. Therefore certain delimitation decisions had to be made in order to make the present research feasible.

i) Regarding the focus of the research it was decided to focus on the students in preference to teachers or to mathematics. It is the belief of this researcher that the problem in school mathematics for Bophuthatswana

lies in our lack of understanding of the Tswana school child. We don't know enough about his cognitive structures, his language difficulties, his attitudes to mathematics or the effect of the culture on his learning.

ii) For a theoretical framework which could be used it was decided to use Skemp's (1979) model and to adapt it for the present research as described in section 5.3. below. The adapted model would serve for ordering the empirical data.

iii) The study would involve one high school and its three feeder middle schools as comprising one educational unit in Phokeng. This would provide a standard 7 population of approximately 600 students in eleven classes and it would involve seven mathematics teachers.

iv) Two types of data would be gathered viz information from the whole population by means of questionnaires and then in-depth interviews would be carried out with a 10% sample using the clinical interview method. Personal observation and informal interviews would also be used to provide more background and for validation purposes.

v) Only basic arithmetic word problems would be used for the interviews. No attempt would be made to cover other sections of mathematics such as algebra, geometry or even the more difficult parts of arithmetic like fractions and percentages. The reason for this decision was two-fold: one, it was felt better to work at some

depth on a limited content than to do superficial work on a broader surface; and two, it was felt that the students who were having problems in mathematics had never really mastered the basics such as the four arithmetic operations, and this needed to be investigated.

vi) The main investigation would be carried out on just one group of standard 7 students namely those present in the schools in June 1987. It is well known to experienced teachers that students differ from year to year and what is true for 1987 group may not be true for 1988 or any subsequent group. To control this factor examination results for several years were analysed and no obvious differences could be identified in the performance of std 7 groups over the years.

5.2.3. Limitations and generalizations

Every research aims for generalization of its findings to a wider population. From the discussion in the previous section however, it is clear no overall extension of the present research findings can be claimed to all of Bophuthatswana. Furthermore in view of point vi above it is not even possible to apply the findings to other standard 7 groups apart from the 1987 group investigated. But research must begin somewhere and the present study looked at the Bafokeng region in Bophuthatswana and selected the Phokeng educational unit of that region for analysis. It is reasonable therefore

to extend the conclusions of the Tlhabane circuit of education which includes the Bafokeng region which has Phokeng as its capital.

Phokeng is neither an urban township nor a rural village; in some senses it is unique in Bophuthatswana, being a traditional African village which is situated beside the very rich platinum mines. This can be regarded as an advantage or a disadvantage vis a vis the generalizability of the research findings. From one point of view the findings cannot be applied to any other district because of Phokeng's unique features, but this researcher rejects such a limited approach.

The Bafokeng belong to the larger class of Tswana people with whom they share the same language and customs. Clearly their tribal history and the manner in which they have reacted to change are peculiar to themselves as was shown in chapter 1. On the other hand the economic pressures of the nineteen eighties and the political groupings and so on are similar to those faced by other groups in Bophuthatswana. Seen from this viewpoint the findings of the present research into success and failure in mathematics can be accepted as shedding light on the wider Bophuthatswana area, providing a deeper understanding of mathematics for the whole country. It is certainly fair to extend the conclusions to the Tlhabane circuit and with a great deal more caution some of the findings can be extended to

Bophuthatswana as a whole. The sections which may be generalized include the analysis of the Tswana language and degree of westernization dealt with in chapter 7 and the teaching styles given in chapter 8. The same degree of certainty cannot be claimed for the socio-economic findings of chapter 7 and the material reported in chapter 9. The findings of chapter 6 on the performance of 60 std 7 students in the picture problems can reasonably be generalized to the whole std 7 population of the educational unit studied but no claims of wider generalization can be made.

In order to extend the findings of the present research to all Bophuthatswana several studies along the lines proposed here would have to be undertaken - at least one in each of the seventeen educational circuits. Furthermore statistical precautions to ensure proper randomization would have to be taken.

5.3. Theoretical framework

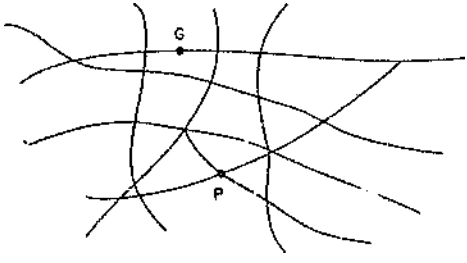
As noted at the end of the previous section the focus of this research was on the student and the main aim was to compare successful and unsuccessful mathematics students within the Tswana culture. Romberg (1982) speaks about research into the learning of mathematics operations as suffering from the serious drawback of not having a generally accepted paradigm (P.2). This has led to a great proliferation of facts but no theory to make sense

of the facts. In this research Skemp's (1979) theory was used in the main and the theoretical framework for the research was based on Skemp's model of intelligence. Skemp develops this model in his book entitled: Intelligence, Learning and Action published in 1979. The chief reasons for this selection were firstly, Skemp's own interest in the teaching and learning of mathematics, as a teacher, a researcher, and author; secondly because this model provides a structure appropriate for the study of the Tswana way of doing mathematics.

Skemp describes intelligence as a goal directed activity - a process not an object - and he elaborates his model in terms of a director system which applies itself to the attainment of goals. In order to do this the system must have some means of identifying its present state vis a vis the desired goal state and some way to compare the two. The other components are a part which is sensitive to the environment, called a sensor and a part which determines what happens when the object is not in its goal state called a plan (ibid P.42). A brief description of the director system is given in chapter 3 above section 3.2.4 and fig 3.3. Skemp (1979, chapter 10) fills out in more detail the connection between goal state (G) and present state (P) by means of a diagram in which knots represent concepts and lines represent connections between concepts and the whole complex is a

sort of cognitive map which he calls a "schema", as shown in Fig 5.1.

Fig 5.1. Cognitive map of present state and goal state



G: Goal state P: Present state Skemp (1979, P.144).

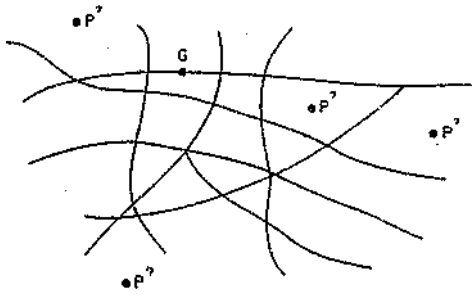
With reference to these cognitive maps, Skemp says:

> Our schemas are at the core of viability, in any universe of discourse: be it literally finding our way to the place we want to be, or the complex and abstract paths by which we move from awareness of a problem to its solution (ibid P.144).

By means of a similar diagram Skemp conceptualises the idea of "understanding". He says the achievement of understanding is the making of connections between an isolated unconnected point (P) with an existing schema. In Fig 5.2. the present state (P) is shown as a point which is not connected to any existing schema in the person's mind. Since he cannot therefore move from this isolated state to the desired goal state (G) we say understanding

has not been achieved.

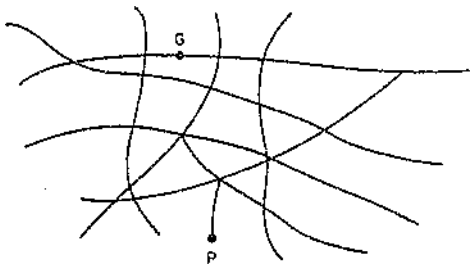
Fig 5.2. Cognitive map to show the state of "not-understood"



Skemp (1979, P.145)

In Fig 5.3. on the other hand the present state (P) is now connected into an existing schema and the person is enabled to move along any number of different routes in order to reach the goal state.

Fig 5.3. Cognitive map to show the state of "understanding"

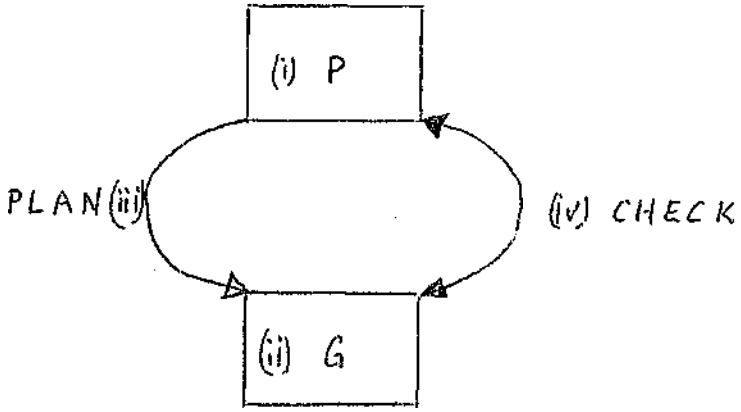


Skemp (1979, P.145)

Furthermore the emotions signal "not-understood" (unconnected P) as frustration and anxiety whereas they signal "understanding" (connected P) as confidence and security (ibid).

As remarked already Skemp's model was given in section 3.2.4. of chapter 3 above. For the purposes of the present research this model was adapted as shown in Fig 5.4.

Fig 5.4. Model used for picture problem tasks



(i) P: present state as perceived by the subject, identified and disembedded from the picture problem

(ii) G: goal state also derived by the subject from the picture

(iii) Plan: the proposed route taken by the subject to move from P to G represented by a single arrow

(iv) Check: the manner the subject checks that the goal has been reached and no errors have been made, rep-

resented by a double arrow

Only two components were used as a basis for the construction of this model, and for the designing of the picture problems in chapter 6. These components were:
i) Present state which was given in the form of pictures and words e.g. Picture problem 2 (Appendix B No.2) contains the key information that Thabo has 8 trees each with 6 apples.
ii) Goal state was given in the form of a question written at the bottom of the picture e.g. in picture 2 just referred to the subject was asked to determine the total number of apples owned by Thabo.
These two components were linked by (iii) Plan which consists of a one way arrow to indicate the route from P to G devised by the subject and (iv) Check which consists of a double arrow to indicate a checking system which would provide information about the solution. The chief advantage of this model is that it provides a framework for categorizing the subject's behaviour as he dealt with each picture problem. This enabled a scoring system to be constructed. Furthermore comparisons could now be made between subjects on the basis of their performance in the picture problems and since these scores provide a rank order for the performance of the subjects in the picture problems the scores could be correlated with the maths examination marks attained in school

tests.

Little work has been done in order to understand how cultural influences operate in the development of schemata among the Tswana. This was researched by investigating the following:

(a) Tswana language;

(b) organisation of data by both groups of students;

(c) self-image;

(d) attitudes of both groups towards mathematics;

(e) cultural beliefs;

(f) socio-economic status.

All of these variables were deemed to affect how the students formed schemata in the first place and the assumption was made that the kinds of schemata available would determine whether or not a student was successful in mathematics.

The strategies used by the two groups of students when solving the picture problems would provide data which might help to distinguish successful from unsuccessful ones, and might enable us to deepen our understanding of how the students perform more generally in mathematics.

5.4. Research instruments

In this research the emphasis was on qualitative data due to the exploratory nature of the study but quantification was done wherever possible. Throughout the research period, observation, non-formal interviews and

small scale tests were used to further deepen our understanding of the problem. The quantitative material was collected by means of four questionnaires administered to all 600 standard 7 students being studied and one written paragraph from each student. The qualitative material was collected by conducting clinical interviews with a 10% sample of the students i.e. approx 60 students. Personal observations etc. were recorded to augment the qualitative data and where appropriate small scale tests were used to augment the quantitative data. In the collection of essays dealing with research into addition and subtraction from a cognitive perspective edited by Carpenter et al (1982), Romberg (1982) discusses the difficulties due to lack of a suitable paradigm for organising the facts gathered by researchers in this field. He does point out however that the data gathering tools are pretty well established:

> ... one feature of an emerging consensus or a paradigm is agreement on methods of inquiry into the questions of critical importance. In the research presented in this volume, clinical interviewing of students is the predominant methodology. Carefully designed tasks and probing questions presented to a small sample of children are accepted as appropriate procedures (P.5).

5.4.1. Quantitative data gathering instruments

(a) Questionnaires:

Four questionnaires were designed for this research and these were tested in the pilot study as described in

Chapter 4, sections 4.5., 4.6., and 4.9., where the development of these instruments was also dealt with.

(i) Attitudes to mathematics were measured using the questionnaire of 35 closed statements (Appendix C) to which the students were asked to reply: agree; don't know; disagree. These questions were based on Husén (1967).

(ii) A set of open ended questions on attitudes to mathematics provided further data and allowed the students to expand on this topic (Appendix D). This instrument was also tested in the pilot study and while it did not provide much quantifiable material it proved very useful for cross checking the scores on the closed instrument.

(iii) Another questionnaire was designed to arrive at a score for cultural beliefs. It consisted of 35 closed ended questions based on McClelland (1975) who presented categories for an analysis of national character. These categories were applied to the Tswana character and reported by White & Kiely (1985) this was tested in the pilot study and redesigned as shown in Appendix E.

(iv) Data on socio-economic status were gathered using another questionnaire of 23 questions as given in Appendix F. This instrument was based on Kiely (1983) who developed it for a study on students in the Bafokeng region of Bophuthatswana.

(b) Paragraph:

Each of the 600 standard 7 students was invited to write

a short paragraph to tell the researcher about himself or herself. The categories for analysing this paragraph were based on the work of Minkowich et al (1982) who did an evaluation study on success and failure in Israeli schools. They analysed self image in terms of: locus of control, anxiety, perceived affection etc. (ibid Chapter 8).

5.4.2. Qualitative data gathering instruments

The major instrument here was the clinical interview which consisted of two parts:

(a) A general discussion with the student about himself, school, home and mathematics. The purpose of this was firstly to build up rapport because conversation with a white man conducted through the medium of English was expected to be a difficult situation for the standard 7 children to cope with. Secondly this provided material on how the student perceived himself in relation to maths, his friends, his maths teacher as well as gathering other data.

(b) The students were presented one at a time with five picture problems as described in Chapter 6. These were based on the work of Hart et al (1981) and consisted of simple addition, subtraction, multiplication and division together with a number-line problem in counting. In each picture there was the figure of a person speaking some Setswana words and underneath was written a

question. The information given was contained partly in the words spoken by the figure in the picture and partly in the drawing itself. Everything the student said and did was recorded. At the start as little direction as possible was given apart from asking the student to say what he was thinking. The researcher avoided giving cues such as smiling or nodding but prompted the student to talk his way through the problem only if necessary. After the student had arrived at an answer or failed to do so in a reasonable time the researcher probed deeper to find out what steps were taken, method used, possibility of checking answer etc. The researcher was sensitive to the following:

What does the student perceive ? Has he the ability to carry out the operation required ? Does he know what the goal state is in the given situation ? Can he devise a plan for achieving the goal state ? How does he carry out this plan ? What mode of reality testing does he use ?

5.4.3. Other instruments

During the time of the research, in the spirit of the illuminative method that was followed, the study was continually deepened by gathering other data as it emerged. Small scale tests was one way in which this was done as described here:

(i) Organisation of data - samples of good and poor

maths students were given a number of small coloured counters of various shapes and asked to sort them into groups. How they did this task was recorded e.g. by trial and error, by counting, by division etc. It was noted how they sorted the counters e.g. by shape or by colour. The differences between good and poor maths students were tabulated.

(ii) Perception - different groups of students were presented with a drawing of a circle and asked to write down what they saw. Groups doing maths were compared with groups doing geography and groups doing biology to discover if they differed in their perception of this figure. The "group embedded figures test" (GEFT) was administered to samples of students to measure their ability to disembed a simple figure from a complex one, and to l out if this was related to their maths marks.

(iii) Language - students were given an arithmetic test consisting of three sets of equivalent problems: one in Setswana, one set in English and the third set using only numbers and arithmetic symbols. Samples of students and some old people were asked to translate words and give Setswana words for various geometrical figures in order to explore how well the concepts of circularity and of rectangularity are developed in Setswana.

(iv) Error analysis was done on the arithmetic test described in (iii) above.

Finally the qualitative instruments of personal observation and informal interviews were continued throughout the research period with attention to the following:

(a) language used by students doing mathematics problems in groups during class.

(b) language used by teachers at morning assembly

(c) problems encountered by students in maths classes

(d) observation of one maths lesson taught by each standard 7 maths teacher in the three middle schools covered by the research.

5.4.4. Summary of instruments

The factors outlined in section 5.3. above in the discussion of the theoretical framework using Skemp's model together with the instruments for gathering data are given in Table 5.1.

5.5. Population and sample

This study concerns mathematics among the Tswana students in the Bafokeng region of Bophuthatswana. The Bafokeng region consists of the area to the north of Rustenburg in the Transvaal; it is approx 40 km long by 25 km wide; its population is estimated to be 97 120; number of children attending primary schools is 16996 for the school year 1982 (Coertze 1987, P.65). The people live in traditional villages as opposed to townships or locations, the more important ones being

Phokeng, Luka, Kana, Tsitseng, Tlaseng and Photsaneng all of which were well established by 1832 (ibid). The region is administered by the Bafokeng Tribal Authority under the control of Chief E.L. Molotlegi, and one of the responsibilities of this authority is the raising of funds for the building of schools in the region.

Table 5.1. Summary of instruments used in the research

FACTOR	INSTRUMENT	
	QUANTITATIVE	QUALITATIVE
Sense modality	none	Observation & interview
Perception	3 small scale tests	Observation & interview
Reasoning	small scale test	Observation & interview
emotional drive	none	Observation & interview
Reality testing	small scale test	Observation & interview
Language	2 small scale tests	Observation
Organisation of data	small scale test	Observation & interview
Self-image	short paragraph small scale test	Observation & interview
Attitudes	2 questionnaires	Interview
Cultural beliefs	questionnaire	Observation
Socio-economic status	questionnaire	Observation
Strategies	small scale tests	Interview

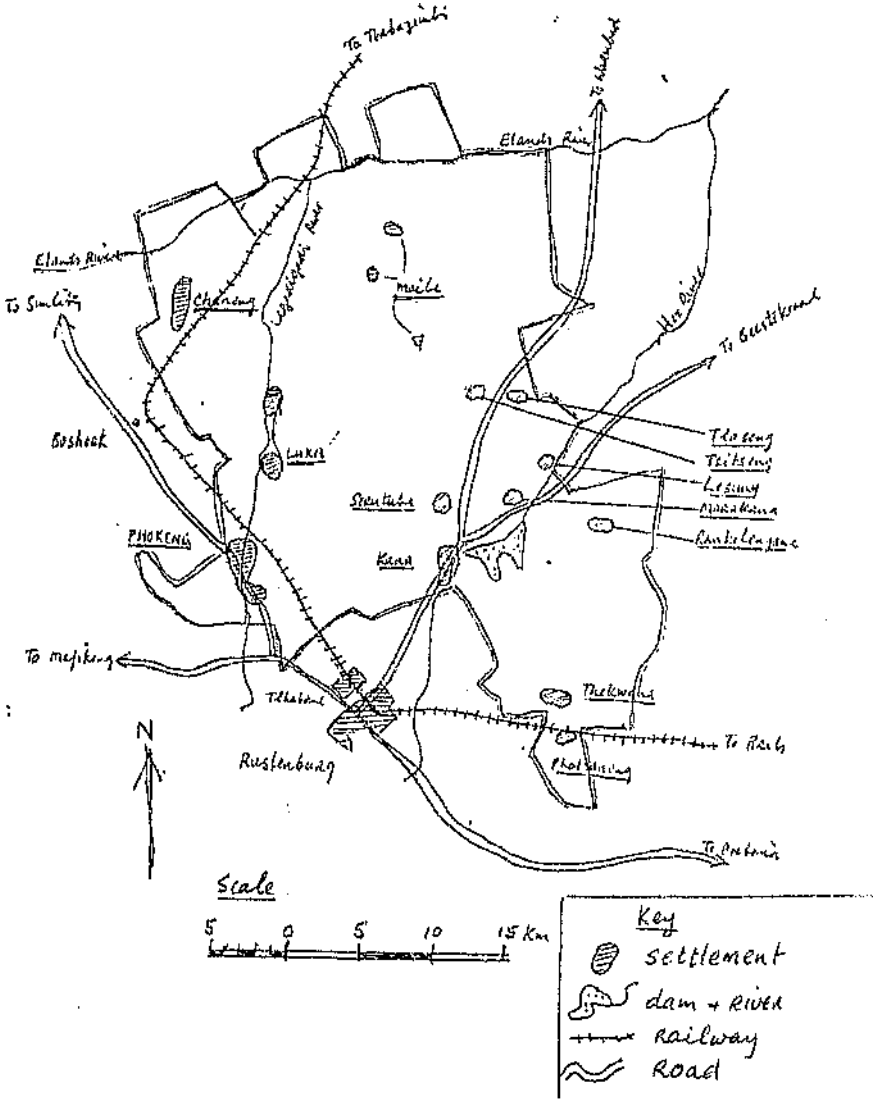
For many years the only secondary school was Bafokeng High School, although in the past ten years five new high schools have been set up in the region. Bafokeng High School was built as a community secondary school in 1940 and moved to a new building in 1963 (Kiely 1983, P.19). Bafokeng High School now serves only the Phokeng and Chaneng villages and it draws its students from the three middle schools in these villages namely: Keledi, Matale and Mafenya middle schools. In 1987 the total school enrolment of Bafokeng High School was 752 students. The enrolment in the middle schools was:

Keledi Middle School	(Phokeng)	1 021
Matale Middle School	(Phokeng)	672
Mafenya Middle School	(Chaneng)	357
	TOTAL	2 050

It must be noted these figures which were gathered from the school Principals in March 1987 may not be absolutely accurate because of high drop-out rates and absenteeism. The numbers could only be finalised by the number of students who sat for the June examination.

It was decided to limit this research to the unit composed of Bafokeng High School plus its three feeder middle schools Keledi, Matale and Mafenya and to focus especially on the standard 7 students.

Fig 5.5. Bafokeng region 1968



Adapted from P.277
Coertze R.D. (1987)

The reason for concentrating on the standard 7 students were (a) it is the last year in school when all students are doing mathematics; (b) it is the year when students sit for the standard 7 public examination; (c) it is the final year of middle school cycle; (d) it is the year in which students must face the decision about their future - whether to continue with their formal education or not and what subjects to select in high school. The standard 7 enrolment for the schools studied is given in Table 5.2

Table 5.2. Standard 7 enrolment for 1987

Name of middle school	number of std 7 classes	number of std 7 students	number of maths teachers
Keledi	4	346	3
Matale	4	190	2
Mafenya	3	132	2
TOTAL	11	668	7

It was decided that quantitative data would be collected from the whole standard 7 population of these three schools and this was to be considered as the students actually present in school on the day the researcher would visit that particular school in June 1987. The

instuments tested in section 4.4.1. above were administered to each student present. It was decided that a sample of approx. 10% would be suitable for the interviews in order to collect qualitative data as described in section 5.4.2. above. Average enrolment per class is just above 40 and it was determined to take four students from each standard 7 class except for Keledi where the numbers were almost double this average and 8 students per class were interviewed from this school.

Table 5.3. Sample drawn from each std 7 class

School	Number of std 7 classes	Enrolment	Number of students interviewed
Keledi	4	346	32
Matale	4	190	16
Mafenya	3	132	12
Total number of students interviewed 60			

The following sampling procedure was used:
half the sample was boys half girls ie. 30 boys 30 girls.
The maths teacher was asked to classify the students into three categories according to (i) good at maths (ii) fair at maths (iii) poor at maths. One boy and one

girl were taken randomly from each group (two in the case of Keledi) but after the first trials the students from group (iii) i.e. "poor at maths" were so deficient in speaking English that there was no point in continuing with this group and it was henceforth omitted. The first major finding of the research emerged in this way. Students who were classified by their teachers as being "poor at maths" were found to be unable to carry on a meaningful exchange about the picture problems through the medium of English. This indicated a close correlation between English fluency and maths achievement. This finding is further developed in Chapter 9.

It was decided to administer the small scale tests described in section 5.4.3. above to students drawn from Bafokeng High School and to avoid using the same subjects for more than one test. Observations were recorded by the researcher when visiting the schools to collect the data. Informal interviews were done with the principals and the mathematics teachers and notes made afterwards. Each std 7 teacher of mathematics in each of the three middle schools was observed teaching mathematics for one complete class period.

5.6. How the data were collected

Data were collected from the population consisting of the educational unit composed of Bafokeng High School and its three feeder middle schools which are Keledi,

Matale and Mafenya middle schools. This was done by the researcher over several years but especially during the period June, July and August 1987. The purpose of the data collection was to study success and failure in mathematics at the standard 7 level. The performance of the students in the standard 7 public examination in mathematics was so bad that it was necessary to interview a sample of the population to determine their level of mathematics ability and the difficulties they experienced as well as the strategies used in solving simple arithmetic problems.

A procedure of random sampling gave a group which contained so many students unable to carry on a conversation in English (approx 30%) that random sampling was abandoned. Instead the mathematics teachers were asked to select students from their classes, students who were "good at maths" and an equal number who were "average". The enrolment in Matale and Mafenya was about 40 per class and so four students (two boys and two girls) were taken from each class. Keledi had up to 80 students enrolled per class and eight students (four boys and four girls) were taken from each class for interview. The interview consisted of talking the students through each of five problems involving separately the four operations of addition, subtraction, multiplication and division and one number line problem. It took between half an hour and one hour for each interview. The whole ex-

ercise took four weeks to complete. The findings of the interviews are reported in Chapter 6 below. A flow diagram illustrating the procedure is given in chapter 10 Fig. 10.1. and Fig. 10.2. Three sets of variables are generally recognised in the literature eg. Alexander and Simmons (1975 , Schiefelbein and Simmons (1978) etc. as having important bearing on academic achievement:

(i) home variables

(ii) school variables

(iii) personal variables

Data on the home variables were collected from the whole population by means of questionnaires designed specially for this research on: (a) socio-economic status and (b) cultural beliefs. The purpose of collecting these data was not cross cultural but (i) to examine these variables for possible correlation with mathematics ability and (ii) to situate each of the sample of 60 students interviewed vis a vis the population. These data are reported in Chapter 7.

The school variables studied were: (a) physical environment of the school and the classrooms (b) relationships between the teachers (c) teaching style of the mathematics teachers (d) in-service training of the mathematics teachers. No special instruments were found to be suitable for this and data were recorded by the researcher as they were observed or heard in informal interviews with the teachers. These data are reported in

Chapter 8.

Personal variables (a) age (b) sex (c) self-concept were collected from all the population by asking each student to complete a form. Four other areas were explored for possible correlation with mathematics ability: (d) common mathematics errors (e) language used by teachers and students in mathematics classes (f) perception of two dimensional drawings (g) organisation of data. Data for these variables were collected over the whole period of the research by personal observation, by informal interviews with students and by some more structured interviews with selected students. The data on the personal variables are reported in Chapter 9.

5.7. Validity and reliability

There are two criteria which measuring instruments in behavioural research must satisfy according to Ary et al (1985, P.213); these criteria are validity and reliability. Other writers agree e.g. Kerlinger (1986, P.391) defines measurement as "the assignment of numerals to objects or events according to rules" and says that while this works well in the natural sciences two major problems must be faced in measurement where we are not able to observe the objects directly but must rely on inference; the problems of measurement now are reliability and validity (P.404). Peak (1953, P.248) discusses a third criterion which she calls "functional