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AN INVESTIGATION INTO SOME LEARNING AND
TEACHING PROBLEMS OF BIOLOGY IN TRANSKEI
SENIOR SECONDARY SCHOOLS

by

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ABSTRACT

The aim of this study was to investigate some learning and teaching problems of biology in Transkei Senior Secondary schools. The research focussed mainly on Biochemistry. Biochemistry was treated in the context of biology as a whole to show its relevance to other sections of the syllabus.

Questionnaires were administered to standard 10 pupils in 15 senior secondary schools selected randomly from the Central Region of Transkei. Further information on pupils' understanding of concepts taught in Biochemistry, was gained through use of concept tests and concept maps.

Interviews were conducted with standard 9 and 10 biology teachers, Subject committee members, Examiners, Subject advisers, Lecturers from the University of Transkei and the Transkei Teachers' In-service College and pupils.

Data obtained through the use of those research methods was analysed and discussed.

Concept mapping as a teaching strategy was introduced to some standard 9 and 10 teachers who attended courses (biology) at The Transkei Teachers' In-service College.

Some suggestions and recommendations for the learning and teaching of biology were then made.

TABLE OF CONTENTS

	<u>Page</u>
CHAPTER 1	
1. INTRODUCTION AND PROBLEM SETTING	1
1.1 Introduction/Motivation for the study	1
1.2 Control of education and provision of schools	6
1.3 Teacher details	11
1.4 Syllabus structure	19
1.5 Teacher perceptions of the syllabus	22
2. AIMS OF THE STUDY	28
3. RESEARCH METHODOLOGY	29
4. LIMITATIONS OF THE STUDY	30
5. AN OVERVIEW OF CHAPTERS	31
CHAPTER 2: REVIEW OF LITERATURE	
2.1 Introduction	32
2.2 Some underlying theories	33
2.3 Some contributions to the constructivist view of learning	36
2.4 Research on pupils' understanding of biology concepts	42
2.5 Some teaching strategies	47
CHAPTER 3: RESEARCH METHODOLOGY	
3.1 Introduction	52
3.2 Questionnaires	52
3.3 Interviews	54
3.4 Concept tests	55
3.5 Concept maps	62
CHAPTER 4: DATA PRESENTATION AND ANALYSIS	
4.1 Responses to pupil questionnaires	64
4.2 Interviews	76
4.3 Responses to concept tests	83

	<u>Page</u>
CHAPTER 5: DATA PRESENTATION AND ANALYSIS	
5.1 Introduction	103
5.2 Photosynthesis concept test	103
5.3 Concept maps	
CHAPTER 6: DISCUSSION OF RESULTS AND RECOMMENDATIONS	
6.1 Introduction	129
6.2 Questionnaires and interviews	129
6.3 Concept tests	130
6.4 Concept maps	149
6.5 Conclusion	149
6.6 Recommendations	153
REFERENCES	155
APPENDICES	161

LIST OF TABLES

<u>TABLES</u>	<u>TITLES</u>	<u>Page</u>
1.1	Std 10 Biology Examination results (HG)	1
1.2	Std 10 Biology Examination results (SG)	2
1.3	Means for other Senior Certificate subjects (HG)	3
1.4	Overall Senior Certificate Examination results	4
1.5	Comparison of Pupils Enrolled for the Senior Certificate and those registered for biology	5
1.6	Decentralised Control of Education in Transkei	7
1.7	Breakdown of Senior Secondary Schools ⁱⁿ Regions	8
1.8	Breakdown of Senior Secondary Schools into Circuits	9
1.9	Academic qualifications of Std 9 Senior Secondary biology teachers	12
1.10	Professional qualifications of Std 9 Senior Secondary biology teachers	13
1.11	Teaching experience of Std 9 Senior Secondary biology teachers	14
1.14	Academic qualifications of Std 10 biology teachers	15
1.15	Professional qualifications of Std 10 biology teachers	16
1.16	Teaching experience of Std 10 biology teachers	18
2.1	A summary of findings by Roth, Smith and Anderson	46
4.1	Ages of pupils (n=308)	64
4.2	Analysis of Physical Science results (n=210)	66
4.3	Analysis of Std 8 biology symbols (n=308)	66
4.4	Responses of easy topics (n=893)	67
4.5	Responses to difficult topics (n=893)	68
4.6	Results for hay-today question for Bell's pupils and Transkei pupils	84
4.7	Results for the villain question for Bell and Transkei pupils	91

<u>TABLES</u>	<u>TITLES</u>	<u>Page</u>
5.1	Responses to problem I Task No. 1	104
5.2	Responses to problem II Task No. 3	105
5.3	Responses to task 5 (problem II)	108
5.4	Responses to task 6 (problem III)	109
5.5	Responses to task 7. subtasks A, B & C	110
5.6	Responses to task 8 (problem IV)	111
5.7	Responses to task II (problem VI)	115
6.1	A summary of the percentages of types of responses for the question "HAY-TODAY"	135
6.2	A summary of the percentages of types of responses for the question "VILLAIN"	138
6.3	A summary of the percentages of types of responses for the question "GROW-TREE"	141
6.4	A summary of the percentages of types of responses for task 12 of the PCT	146
FIGURES :	Figure 1	124
	Figure 2	125
	Figure 3	126

PREFACE

This study originates from my experience as a biology and physical science teacher at Ndamase Senior Secondary School and later a biology lecturer at the Transkei Teachers' In-service College. The poor performance of pupils in Std 10 biology examinations was noticed. I saw a need to investigate some of the causes for the poor performance of pupils in biology examinations.

Prior to this research investigation, the main reasons given for the poor examination results were overcrowded classrooms, lack of facilities and underqualified teachers. There was a need to get hard data rather than subjective opinion on the provision of schools, the qualifications of teachers and the syllabus being taught. It was felt that this would have a bearing on the quality of teaching that would come out of schools.

Further, I was influenced by research which tested some pupils' understanding of selected biological concepts. Those research studies have yielded much valuable information on the ideas held by pupils but no attempts were made to investigate the contributing factors.

It was decided to use some of the diagnostic tests that had been developed in the United States of America and United Kingdom to investigate the Transkei pupils' understanding of some biological concepts.

The results of the tests administered were then analysed and discussed against the background information on schools, qualifications of teachers and syllabuses.

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CHAPTER 1

1. INTRODUCTION AND PROBLEM-SETTING

1.1 INTRODUCTION/MOTIVATION FOR THE STUDY

The performance of pupils in the Senior Certificate Biology Examinations in Transkei triggered the interest in this research. The performance of pupils in Biology over the years has been unsatisfactory. Table 1.1 gives the Biology Examination results taken over a six year period, that is, 1982 to 1987.

TABLE 1.1

STANDARD 10 BIOLOGY EXAMINATION RESULTS (HG)

	1982	1983	1984	1985	1986	1987
No. of Candidates	6950	9601	8459	11634	10553	10593
No. of Passes	3085	3844	2723	2961	4506	3981
No. of Failures	3865	5757	5736	8673	6047	6612
% Failures	55,6	60,0	67,8	74,5	57,3	62,4
Mean	33,0	36,0	34,0	32,0	37,0	36,0

From 1982 to 1985 the percentage of failures rose from 55,6 to 74,5. There was a drop to 57,3% in 1986. In 1986

the old syllabus was examined for the last time. With the examination of the current syllabus for the first time in 1987, there was again a rise in the failure rate from 57.3 to 62.4%

The examination results for the Standard Grade paper are comparatively better. Table 1.2 gives the Standard Grade Biology Examination results.

TABLE 1.2

STANDARD 10 BIOLOGY EXAMINATION RESULTS (S.G.)

	1982	1983	1984	1985	1986	1987
No. of Candidates	158	299	811	775	953	787
No. of Passes	117	242	610	564	746	380
No. of Failures	41	57	201	211	207	407
% Failures	26,0	19,1	42,8	27,2	21,7	51,7

Comparing 1986 and 1987 there is a big rise in the failure rate from 21,7% to 51,7%

A comparison of the number of pupils that enrolled for the H.G. and S.G. Biology Examinations over the six year period shows that the majority of pupils register for Biology at H.G. There may be various reasons for that. For some

pupils, Biology is the only science subject, and to meet the requirements for matriculation exemption, pupils had to register for Biology at H.G. Some manage to get through but others do not. Some pupils feel that Biology S.G. is inferior and would not gain them entry to University, that is, for those who would do BSc or any other science degree. There may also be other reasons.

Biology is not the only subject in which pupils perform badly. As a means of comparison a table of the means for other Senior Certificate subjects is provided in Table 3.

TABLE 3

MEANS FOR OTHER SENIOR CERTIFICATE SUBJECTS (H.G.)

SUBJECT	MEANS					
	1982	1983	1984	1985	1986	1987
Mathematics	22,0	22,0	25,0	25,0	28,0	30,0
Physical Science	28,0	32,0	29,0	24,0	33,0	32,0
History	27,0	28,0	31,0	33,0	36,0	35,0
Geography	23,0	21,0	28,0	28,0	25,0	31,0
Agricultural Science	25,0	25,0	26,0	27,0	31,0	30,0
Biology	33,0	36,0	34,0	32,0	37,0	36,0

Table 1.3 shows that comparatively, the performance in Biology, although not satisfactory, is better than in the

subjects listed. This shows that on the whole the performance of pupils in Transkei Senior Certificate Examinations is poor. This is further made explicit in Table 1.4 which shows the overall Senior Certificate Examination results in Transkei Senior Secondary Schools in the six year period, that is, 1982 to 1987.

TABLE 1.4

OVERALL SENIOR CERTIFICATE EXAMINATION RESULTS

	1982	1983	1984	1985	1986	1987
No. of Candidates	8350	10299	11100	12853	12039	13036
No. of Passes	3474	4977	4305	5149	5779	6123
No. of Failures	4876	5322	6795	7704	6260	6913
% Failures	58,4	51,7	61,2	59,9	52,0	53,0

If one compares the number of pupils enrolled for the Senior Certificate Examinations in this six year period with the number of pupils entering for the Biology Examinations, one could argue that the greatest majority of pupils registered for the Senior Certificate do Biology. This comparison is shown in the following table 1.5.

TABLE 1.5

A COMPARISON OF PUPILS ENROLLED FOR THE SENIOR CERTIFICATE AND THOSE REGISTERED FOR BIOLOGY

	1982	1983	1984	1985	1986	1987
Total number of Candidates	8350	10299	11100	12853	12039	13036
No. of Biology Candidates (Both HG & SG)	7108	9900	9270	12409	11506	11380
% Age	85,1	96,1	83,5	96,5	95,6	87,3

The poor performance of pupils in the Senior Certificate Examinations in general, and in Biology, in particular is the cause for concern. There may be various reasons for the poor pupil performance. These may include the following:

- (i) Lack of basic school facilities.
- (ii) Unqualified or underqualified teachers.
- (iii) Syllabus structure.
- (iv) Large classes - teacher - pupil ratio may be unbearable.
- (v) Lack of teaching strategies aimed at concept development.
- (vi) Textbooks used.
- (vii) Types of examinations set.
- (viii) Teaching through a second language.

This study cannot be in a position to investigate all the

possible reasons for the poor performance of pupils in examinations, although the researcher is aware of the need to do so. It is therefore appropriate to look at the control and provision of schools in Transkei, conditions of the schools, syllabus structure and teachers.

1.2 CONTROL OF EDUCATION AND PROVISION OF SCHOOLS

Transkei was granted independence by the Republic of South Africa in 1976. On attainment of independence Transkei adopted the Cape Education Syllabus for schools. The medium of instruction is English. Transkei, is, however, responsible for its own examinations.

Control of education in Transkei is centralised, although there is a limited amount of decentralisation into five regions. Transkei is divided into five regions, namely, Northern, Southern, Eastern, Western and Central regions with Headquarters respectively at Umzimkulu, Butterworth, Mt Ayliff, Lady Frere and Umtata. The decentralised control of education in Transkei is shown in table 1.6.

TABLE 1.6

DECENTRALISED CONTROL OF EDUCATION IN TRANSKEI

REGION	CIRCUITS	HEADQUARTERS
Southern	Butterworth; Nqamakwe, Tsomo, Kentani; Willowvale; Idutywa	Butterworth
Western	Engcobo; Ezibeleni; Lady Frere; Xalanga; Herschel St Marks	Lady Frere
Eastern	Mt. Ayliff; Mt. Frere; Tabankulu; Flagstaff; Lusikisiki	Mt. Ayliff
Northern	Bizana; Mt. Fletcher; Maluti; Umzimkulu	Umzimkulu
Central	Umtata; Qumbu; Tsolo; Libode; Port St Johns; Ngqeleni; Elliotdale; Mqanduli	Umtata

In each region, there is a regional inspector. Transkei has 29 inspection circuits each with a circuit inspector and a number of assistant inspectors.

By June 1988 there were 247 Senior Secondary Schools and 1585 Junior Secondary Schools in Transkei. The division of schools in Transkei is in line with the provisions of the twelve year structure introduced in South Africa in 1974. Transkei decided on the following pattern:

Sub A - Std 1 -> Junior Primary
 Std 2 - Std 4 -> Higher Primary
 Std 5 - Std 7 -> Junior Secondary
 Std 8 - Std 10 -> Senior Secondary

These are separate schools under different headmasters, unlike in CED or other education departments where there are two divisions, that is, Sub A to Std 5 and then Std 6 - Std 10.

The breakdown of senior secondary schools into the five regions is given in Table 1.7.

TABLE 1.7

BREAKDOWN OF SENIOR SECONDARY SCHOOLS INTO REGIONS

<u>REGION</u>	<u>NO. OF SCHOOLS</u>
Southern	47
Western	50
Eastern	40
Northern	42
Central	68

	247

The break down of schools into circuits is given in Table 1.8.

TABLE 1.8

BREAKDOWN OF S.S.S. INTO CIRCUITS

CIRCUIT	NO. OF SCHOOL		NO. OF CLASSES	
	J.S.S	S.S.S.	PERM.	TEMP.
1. Bizana	66	10	47	23
2. Butterworth	40	08	63	13
3. Elliotdale	31	03	21	02
4. Engcobo	75	08	48	17
5. Ezibeleni	37	10	125	06
6. Flagstaff	46	06	38	10
7. Herschel	47	09	86	05
8. Idutywa	51	08	31	31
9. Kentani	52	09	40	18
10. Lady Frere	51	08	75	-
11. Libode	55	08	40	21
12. Lusikisiki	62	12	96	37
13. Maluti	61	13	86	40
14. Mt. Ayliff	42	04	23	03
15. Mt. Fletcher	55	07	18	49
16. Mt. Frere	78	10	84	07
17. Mqanduli	42	07	32	15
18. Ngqeleni	56	09	26	39
19. Nqamakwe	67	08	75	18
20. Port St Johns	25	04	08	19
21. Qumbu	69	10	79	27
22. St. Marks	61	09	65	06
23. Tabankulu	51	08	43	24
24. Tsolo	60	07	79	10
25. Tsomo	51	05	26	05
26. Umtata	77	20	224	39
27. Umzimkulu	69	12	47	45
28. Willowvale	69	09	46	29
29. Xalanga	39	06	33	19
Total:	1585	247	1704	577

The Junior Secondary Schools are supposed to send pupils who go through them to S.S.S. If one compares 1585 Junior S.S. with 247 S.S.S. one wonders how 247 S.S.S. could accommodate pupils from 1585 J.S.S. There is generally a shortage of classrooms and seating accommodation. Of the 247 S.S.S. only 139 schools exist physically, that is, have been built. Table 1.8 shows that there are 1704 permanent classrooms and 577 temporary classrooms. These temporary classrooms are sometimes classrooms borrowed from nearby Junior S.S.; huts, rooms etc. borrowed from the Community. In cases where there are optional subjects within one class some pupils are taught outside. If it rains or it becomes too cold for some pupils to go out one group of pupils is not taught. This poses a serious problem to teachers who are compelled to teach despite the appalling conditions of the schools in which they find themselves.

The problem of shortage of classrooms and seating accommodation is more severe in some circuits than in others. From Table 1.8 it can be seen that the severely affected circuits are Bizana, Engcobo, Mt Frere, Qumbu, Umzimkulu Willowvale and Umtata. In the following circuits the problem is less severe: Lady Frere, Ezibeleni and Herschel. Shortage of classrooms and seating accommodation is a serious problem in Transkei Senior Secondary schools. Lady Frere, Ezibeleni and Herschel were incorporated into Transkei in 1976. They had been previously under Ciskei.

1.3 TEACHER DETAILS

Information on teachers was obtained by an analysis of the biographical questionnaires completed by teachers attending courses at the Transkei teachers' In-Service College (herein referred to as Trinset). It was noted that only a small percentage of the teachers attended both the Std 9 and Std 10 biology courses. As a result of this, information on teachers attending the Std 9 and Std 10 courses is given to provide a fuller picture of the qualifications, and teaching experience of senior secondary biology teachers.

1.3.1 Standard Nine Biology Teachers

1.3.1.1 Teacher Qualifications

One of the factors influencing pupil performance is the quality of the teaching they receive and it is therefore important to investigate the academic and professional qualifications of the biology teachers. This investigation (as stated earlier on) was undertaken by an analysis of the biographical questionnaires completed by teachers who attended the Std 9 and 10 biology courses in 1988. Information on the Std 9 biology teachers will be considered first.

Table 1.9 gives a summary of the academic qualifications of the Senior Secondary biology teachers who attended the Std 9 biology course in April 1988.

TABLE 1.9

ACADEMIC QUALIFICATIONS OF STD 9 SENIOR SECONDARY BIOLOGY TEACHERS

ACADEMIC QUALIFICATION	REGIONS					TOTAL	%AGE
	SOUTH-ERN	WEST-ERN	EAST-ERN	NORTH-ERN	CENTRAL		
Matric	28	15	13	17	11	84	67,7
BA / B.Com	-	1	3	-	1	5	4,0
B.Sc.	6	1	2	1	12	22	17,7
Hons. Degree	-	-	1	1	-	2	1,6
Masters and above	1	-	1	-	1	3	2,4
GCE "A" Level	1	1	-	-	2	4	3,2
No Response	-	-	-	-	4	4	3,2
TOTAL :	36	18	20	19	31	124	

67,7% of these teachers had Matric as the highest academic qualification and only 17,7 % held a BSc degree. Of the 22 BSc graduates, 12 came from the Central region of Transkei. This may be due to the fact that the Central region is the biggest or that teachers are not far from the University of Transkei. Expatriates are also concentrated mainly in the Central, Southern and Western regions.

The professional qualifications of the teachers are shown in in Table 1.10.

TABLE 1.10

PROFESSIONAL QUALIFICATIONS OF STD 9 SENIOR SECONDARY
BIOLOGY TEACHERS

PROFESSIONAL QUALIFICATION	REGIONS					TOTAL	%AGE
	SOUTH- ERN	WEST- ERN	EAST- ERN	NORTH- ERN	CENTRAL		
PTD	4	2	-	2	1	9	7,3
JSTC	7	4	2	2	1	16	12,9
STD	16	8	10	13	6	53	42,7
HPTC	1	-	1	-	2	4	3,2
SSTD	-	1	-	-	3	4	3,2
UED/HDE/HED	-	-	2	1	5	8	6,5
None	5	2	2	-	6	15	12,1
Other (mainly Dip. in Educ)	3	1	3	1	3	11	8,9
No Response	-	-	-	-	4	4	3,2
TOTAL :	36	18	20	19	31	124	100,0

42,7% of the teachers held the Secondary Teachers' Diploma the entrance qualification for which is Senior Certificate 6,5% had University training, that is, UED/HDE/HED. This means that about 50% of the teachers are actually trained to teach at Senior Secondary school. An observation by Trinset staff is that although the Expatriates have high academic qualifications quite a number of them have no professional qualifications.

1.3.1.2 Teaching Experience in Biology

The researcher saw it necessary to look at the teaching experience of biology teachers. This was done by analysing the biographical questionnaires of the teachers attending courses at Trinset. The teaching experience was divided into five categories. Table 1.11 shows the results.

TABLE 1.11

TEACHING EXPERIENCE OF STD 9 SENIOR SECONDARY BIOLOGY TEACHERS

TEACHING EXPERIENCE	SOUTH-ERN	WEST-ERN	EAST-ERN	NORTH-ERN	CENTRAL	TOTAL	%AGE
Less than 1 year	3	4	2	-	6	15	12,1
1 - 5 years	21	12	13	15	13	74	59,7
6 - 10 years	8	1	4	-	4	17	13,7
11 - 15 years	3	-	-	-	2	5	4,0
16 - 20 years	-	-	-	-	2	2	1,6
21 and above	1	-	1	-	-	2	1,6
No response	-	1	-	4	4	9	7,3
TOTAL :	36	18	20	19	31	124	

59,7% of the teachers fell in the (1-5) years category of teaching experience in the subject. Some teachers had just taught for a few months. The majority of these teachers were not experienced enough to handle the subject with confidence.

The information that will be considered next is on the teachers who attended the Std 10 Biology Course in August 1988.

1.3.2 Standard Ten Biology Teachers

155 teachers attended the course. Of the 155 teachers who attended the Std 10 biology course only 12 teachers attended the Std 9 biology course in April 1988.

1.3.2.1 Teacher Qualifications

The information on academic qualifications of teachers is provided in Table 1.12.

TABLE 1.12
ACADEMIC QUALIFICATIONS OF STD 10 BIOLOGY TEACHERS

ACADEMIC QUALIFICATION	REGIONS					TOTAL	%AGE
	SOUTH- ERN	WEST- ERN	EAST- ERN	NORTH- ERN	CENTRAL		
Matric	26	17	23	12	12	90	58,1
BA/Equivalent	2	1	2	3	6	14	9,0
B.Sc	6	5	6	1	14	32	20,6
Hons/B ED	-	1	1	-	2	4	2,6
Masters	-	2	2	-	3	7	4,5
Ph D	-	-	1	-	1	2	1,3
GCE "A" level	1	-	-	-	-	1	0,6
Other	-	-	-	-	1	1	0,6
No response	-	-	3	-	1	4	2,6
TOTAL	35	26	38	16	40	155	

Of the 155 teachers 90 (58,1%) had Matric or Senior Certificate as their highest academic qualification. There were 32 B Sc graduates, that is, 21% of the total number of teachers who attended the course, 9% of whom come from the Central region of Transkei.

Table 1.13 provides information of the professional qualification of teachers who attended the Std 10 biology course.

TABLE 1.13

PROFESSIONAL QUALIFICATIONS OF STD 10 BIOLOGY TEACHERS

PROFESSIONAL QUALIFICATION	REGIONS					TOTAL	%AGE
	SOUTH- ERN	WEST- ERN	EAST- ERN	NORTH- ERN	CENTRAL		
PTD	2	2	1	1	1	7	4,5
H P T C	3	3	2	-	4	12	7,7
S.T.D.	11	7	12	10	6	46	29,7
UED/HED/HDE	2	1	5	-	8	16	10,3
J.S.T.C	6	5	7	3	5	26	16,8
S.S.T.C	1	-	-	-	1	2	1,3
Other	4	1	1	1	5	12	7,7
None	5	7	7	1	8	28	18,1
No response	1	-	3	-	2	6	3,9
TOTAL	35	26	38	16	40	155	

Teachers who hold a Primary Teachers' Diploma (PTD), Higher Primary Teachers' Certificate (HPTC) and Junior Secondary Teachers' Certificate (J.S.T.C.) were never trained to teach at Senior Secondary Schools, but they do. These teachers constitute twenty nine percent (29%) of the teachers who attended the Std 10 Biology Course. 29,7% of the teachers investigated had Secondary Teachers' Diploma (STD) as their professional certificate. 10,3% had University training and 18,1% had no professional certificate mainly expatriates. 49% of the total number of teachers were trained to teach at Senior Secondary Schools. In all, about 50% of the teachers who teach Std 9 & 10 are qualified or trained to teach at Senior Secondary School.

1.3.2.2 Teaching experience in Biology

As was the case with the Std 9 biology teachers, the teaching experience of the teachers who attended the Std 10 biology course was divided into five categories. The information on the teaching experience is provided in Table 1.14.

TABLE 1.14

TEACHING EXPERIENCE OF STD 10 BIOLOGY TEACHERS

TEACHING EXPERIENCE	REGIONS					TOTAL	%AGE
	SOUTH- ERN	WEST- ERN	EAST- ERN	NORTH- ERN	CENTRAL		
< than 1 year	5	1	2	7	7	22	14,2
1 - 5 years	24	13	23	7	19	86	55,5
6 - 10 years	3	6	6	2	5	22	14,2
11 - 15 years	1	4	1	-	3	9	5,8
16 - 20 years	-	2	2	-	3	7	4,5
21 and more	-	-	1	-	-	1	0,6
No response	2	-	3	-	3	8	5,2
TOTAL	35	26	38	16	40	155	

14,2% of the teachers investigated had an experience of less than a year, while 55,5% had an experience of less than five years. In all, 69,7% of the teachers could be considered inexperienced. We saw the same pattern for the teachers who attended the Std 9 Biology Course.

From the information about teachers, one could infer that Transkei teachers are - on the whole, underqualified. These teachers therefore have teaching problems. Gavin Relly, chairman of Anglo American Corporation and De Beers

Consolidated Mines on the official opening of TRINSET on 14 April 1986 remarked that "more than 70% of Transkei teachers were underqualified for the education of Transkei children".

Although Transkei Teachers are underqualified, they are faced with a syllabus they are compelled to teach. For most of the Biology teachers, the current syllabus is difficult to teach. The syllabus is there and it has to be taught.

1.4 Syllabus Structure

Changes in the Biology syllabus over the years have resulted in the introduction of new sections in the syllabus. These sections include Biochemistry, Ecology, Population Dynamics and Homeostasis. Biochemistry was introduced in the Biology syllabus in 1968 and was examined for the first time in 1970.

The current syllabus begins with Ecology in Std 8 and closes with Population Dynamics in Std 10. It was examined for the first time in Std 10 in 1987. Before the introduction of the new sections of the syllabus, Biology was comprised primarily of Anatomy and Physiology - both plant and animal anatomy and physiology. There was little concern of the relationship between plants, animals and the environment in which they live. Physiology was taught in a descriptive way rather than requiring an understanding of molecular processes. Teachers

who did Biology in the sixties were therefore taught Anatomy and Physiology, and, except for those who proceeded to Universities have no sound background of Biochemistry, Ecology and Population Dynamics. Since Biochemistry deals with the chemical substances and chemical processes of living organisms it therefore lays a foundation for the understanding of other sections of the syllabus that is, Ecology and Physiology. The Biochemistry topics as laid down by the current syllabus include the following:

- (i) Chemical composition of protoplasm.
- (ii) Relevant functions of water and proteins.
- (iii) Nucleic Acids.
- (iv) Protein synthesis and gene mutations.
- (v) Biological compounds and nutrients
 - water, macro and micronutrients
 - organic compounds:- carbohydrates, lipids, proteins, vitamins.
- (vi) Enzymes and co-enzymes.
- (vii) Photosynthesis.
- (viii) Cellular respiration.
- (ix) Chemical processes of digestion.

The conceptual structure of the syllabus also poses problems. Pupils are expected to be taught Genetics, Nucleic Acids, and

some protein synthesis in Std 9. The bulk of Biochemistry is treated in Std 10. It is surprising that pupils can be taught Nucleic acids when they have not done Carbohydrates, because they need to know about Ribose and Deoxyribose sugars which are constituents of Nucleic Acids. They deal with protein synthesis before even knowing something about amino acids which are the building blocks of proteins.

Textbook authors do not reorganise the syllabus topics to encourage conceptual understanding. Some teachers follow the textbook order of topics in their teaching. If the teachers are unable to link different sections of the syllabus which are related, pupils tend to compartmentalise their work. This leaves gaps in their understanding of certain concepts and thus continuity becomes impossible.

What I have noted in my experience as a Biology teacher is that pupils cannot link cellular respiration with the respiratory system; proteins, enzymes and enzyme controlled reactions; photosynthesis, plant nutrition, plant water relations and biological compounds, for example.

If the pupils are not shown how these topics relate to one another they will not be able to see the relationships. If the Std 9 teacher is not conversant with the Std 10 syllabus he is unable to foresee what he is preparing his

pupils for, and if on the other hand, the Std 10 teacher is not conversant with the Std 9 work he will not know where to start teaching a topic like, for example, enzymes. Std 9 or even Std 8 work ought to be the starting point for introducing the topic, to test pupils' existing knowledge.

In Transkei Senior Secondary Schools it is common to find a teacher teaching a subject, for example, in about four Std 10 classes but not teach the subject in either Stds 8 or 9 and this can happen for some years. Another practice is that a teacher will teach a subject in Std 9 that particular year and then in Std 10 the following year. This is a better arrangement because at least the teacher is conversant with Std 9 and Std 10 work. This separation of Std 9 and Std 10 may be due to the fact that teachers are underqualified and may prefer to stick to one class. Or the teacher who takes his Std 9 pupils to Std 10 does not want to be blamed if the performance of pupils in Std 10 becomes unsatisfactory. There may be many other factors, like, for example, staff mobility and inconsistencies in subject allocation. A teacher may teach Biology this year and history the following year.

1.5 Teacher Perceptions of the Syllabus

The poor pass rate in Senior Certificate Biology points to some problems in Biology teaching. Teachers who attended courses at the Transkei Teachers' In-Service Training College

in 1986 and 1987 were asked to complete a questionnaire and listed the following topics as problem areas, that is, areas they see as posing problems when teaching. The topics are given in the order of most frequently mentioned to least frequently mentioned.

Std 9

Genetics
Protein Synthesis
Nucleic Acids
Cell Division
Evolution

Std 10

Nervous System
Cellular Respiration
Homeostasis
Photosynthesis
Plant Water Relations
Chemical Co-ordination
Kidney Functioning
Population Dynamics
Enzymes and Co-enzymes
Energy Flow
Biological Compounds
Gaseous Exchange

The following sections continued to occur in 1988 and 1989.

Std 9

Protein Synthesis

Genetics

Human Reproduction

Std 10

Population Dynamics

Homeostasis

Plant Water Relations

Cellular Respiration

Photosynthesis

Enzymes and Co-enzymes

The Examiners' reports reflected poor pupil performance in cellular respiration; plant water relations, population dynamics, chemical processes of digestion, photosynthesis, homeostasis, nutrient elements and vitamins. Std 9 syllabus is not examined in detail - though some related concepts could be examined.

The following are extracts from the Examiners' reports for 1985, 1986, 1987 and 1988 Biology H.G.:

1985 : Lack of knowledge of basic facts, for example osmo-regulation; sex determination.

1986 : Experimental work poorly done. Influence of humidity on the rate of transpiration; test for glucose.

1987 : " Surprisingly candidates performed hopelessly on cellular respiration. The general impression would be that cellular respiration was never taught in most schools.

Most candidates performed equally hopelessly on on absorption of water from the soil by root hairs.

The sub-question on population dynamics revealed that this section of the syllabus has not been introduced at all. On the essay on digestion of proteins and fats most candidates scored at the most 20/60 marks. The essay question on autotrophic organisms was very unpopular. Photosynthesis was not favoured by the candidates at all.

1988 : "The general performance of the candidates was very weak. Candidates who received proper tuition passed well, but most candidates had problems with biochemistry and populations dynamics.

Candidates performed poorly in the sub-question on cellular respiration.

Candidates were asked to describe a test for glucose but instead they presented a test for starch.

Very few candidates attempted the question on the maintenance of a relatively constant body temperature in homiothermic animals."

Biology Standard Grade

Candidates were reported to show some weaknesses in the following topic areas:

1985

Genetics

Plant Water Relations

Proteins

Homeostasis - temperature regulation in mammals

Chemical processes of digestion

Carbon cycle

Ingestion, digestion and egestion in Amoeba

1986

Ecology

Genetics

Cell duplication

Animal and plant diversity

Reproductive processes, life cycles and
alternation of generations."

Other remarks - the following should be considered by
teachers:

- (i) Practical nature of the subject.
- (ii) Some textbooks with wrong or outdated information.
- (iii) Language problems - short sentences preferred to
long sentences.

1987

It is suggested that tutors and candidates should study thoroughly the new sections of the syllabus, for example, population dynamics, homeostasis, plant water relations, nutrient elements and vitamins. Attendance of in-service courses is also very important.

1988 : The performance of the candidates was, in general, not satisfactory at all. The candidates reflected a poor language expression, a lack of adherence or misunderstanding of basic biological concepts, for example, homeostasis, osmotic potential, population dynamics, endocrinology and nutrition.

Basic concepts on plant water relations is not known.

It is very disappointing to note that candidates especially full time candidates still do not know anything or very little of the basic concepts of homeostasis, digestion osmoregulation and water transport through xylem tissue. These are important sections which need thorough treatment.

The Std 9 topics listed or identified by teachers as problem areas and by the examiner for S.G. are mainly Biochemistry topics. Biochemistry covers a greater part of the Biology syllabus. It would appear that Transkei schools are committed to a syllabus which is unteachable for many teachers.

The Biology topics perceived as difficult by teachers and by pupils from the Examiners reports include biochemistry, plant water relations, homeostasis and co-ordination and population dynamics. The topics so mentioned appear to be similar to those listed by Johnstone and Mahmoud (1980); namely,

1. DNA and RNA.
2. Cell structure and cell division.
3. Chemical energy, ATP and ADP.
4. Chemistry of photosynthesis.
5. Chemistry of respiration.
6. Gas exchange between living organisms and their environment.
7. Osmosis and water potential.
8. Role of the kidney.
9. Water balance problems and

- osmoregulation in living organisms.
10. Reproduction and growth in living organisms.
 11. Hormones.
 12. Gametes.
 13. Genes.
 14. Evidence for evolution.
 15. Mechanism of evolution.

2. AIMS OF THE STUDY

The study aims at introducing teachers and pupils to some teaching strategies which take account of the prior ideas or alternative conceptions of the learners. Pupils at school come from different backgrounds with different experiences. Some of them may have been taught by different teachers with different experiential backgrounds. Thus it becomes important for teachers to find out what pupils know about any topic to be taught in class.

The study aims at introducing teachers to teaching strategies which acknowledge that learning involves the active construction of meaning on the part of the learner and which view learning as the reorganisation and development of pupils' conceptions.

This the researcher hopes to achieve by making use of teaching strategies which attempt to promote conceptual change/development in some selected topic areas. For a start use will be made of concept tests and concept maps. Teachers will then be in a position to look critically at the conceptual structure of the syllabus and the textbooks currently in use.

This points to a need for in-service training of teachers in this regard. Biology should be taught in a way that encourages conceptual understanding and not rote learning. The poor results in the Senior Certificate Biology may hopefully improve with time.

Recommendations and suggestions for the teaching of Biology at Senior Secondary level in Transkei will be made.

3. RESEARCH METHODOLOGY

A variety of methods to collect data was employed.

- i) Questionnaires were sent to Std 10 pupils from 15 senior secondary schools selected randomly from the Central Region of Transkei.
- ii) Interviews were conducted with Std 9 & 10 teachers subject Committee members; Examiners; Biology subject adviser, Lecturers from the Transkei Teachers In-service College and pupils.

- iii) Concept tests were administered to Std 10 pupils and to teachers attending Courses at the Transkei Teachers In-service College.

- iv) Concept mapping as a teaching strategy was introduced to teachers teaching at Senior Secondary School level, that is, Std 8, 9 & 10, and to pupils in one school.

4. LIMITATIONS OF THE STUDY

Whilst the researcher is aware that Biochemistry, Ecology, Homeostasis, Plant Water Relations, Population Dynamics etc. are problem areas that need to be researched into, to cover all these sections, would be beyond the scope of this research project. The research is therefore going to focus on some selected Biochemistry topics.

Current national policy statements suggest that science in secondary schools should have a number of types of outcome (DES 1985; SSCR 1983) including the development in pupils of practical skills, processes of thinking, knowing of scientific concepts as well as the development of more general attitudes to knowledge and the environment. The project is going to focus on some teaching strategies aimed at conceptual understanding and not rote learning - though it recognises that through this other aims may be achieved.

5. AN OVERVIEW OF CHAPTERS

Chapter 1 covers mainly introduction and statement of the problem under investigation. Chapter 2 will focus on how pupils learn. Related literature on how pupils learn will be reviewed. Chapter 3 discusses research methods used in this study. Chapters 4 and 5 will be on data presentation and analysis. Chapter 6 will look at possible suggestions and recommendations.

CHAPTER 2

2.1 REVIEW OF LITERATURE

2.1 INTRODUCTION

In this chapter focus will be on the current debate on learning in science. Science educators have shown interest in studying children's ideas about the natural and physical environment. It has become widely accepted that children develop ideas and beliefs about the natural world long before they are formally taught. These ideas and beliefs are varied and have been found to influence learning. Further, these ideas and beliefs have been given a number of names, including alternative frameworks, children's science, alternative conceptions and mini-theories. (Driver and Oldham 1986).

The new terminology, that is, alternative frameworks, children's science, for example, point to a shift that has taken place in the dominant views on learning among psychologists, towards a cognitive perspective which acknowledges that individuals construct "models" or "schemes" which are used to interpret their experiences. This view is the constructivist view of learning, and research in a number of areas of complex human cognitive functioning is premised on this view. Here emphasis is on the role that concepts and conceptual frameworks play in the human construction of meaning.

2.2 SOME UNDERLYING THEORIES

Two theories which have influenced much of present day teaching are the Piagetian theory and Ausubel's theory of meaningful learning. The Piagetian theory of cognitive development emphasised age - related restrictions on what learning can be expected of a child at a certain age. Hence Piagetian theory is seen to fall in the developmental tradition or view. The four successive stages in Piaget's theory of human cognitive development are sensory - motor (birth to age 2); pre-operational (age 2 to 7); concrete operational (7 to 11) and formal operational (age 11 through to adulthood). All individuals from infancy through adolescence progress through these four stages in an "invariant sequence." The analogous constructs employed by Bruner to account for cognitive growth are the enactive, iconic and symbolic representation of experience (Osborne and Wittrock 1985).

Although Piaget is criticised for his age restricted theory, Kamii and de Vries in Osborne and Wittrock (1985) pointed out that Piaget was a constructivist because he considered that :-

- i) all knowledge is constructed by the individual as he or she interacts with the environment and tries to make sense of it; and

- ii) all knowledge is acquired not by the internalisation of some outside given meaning, but by construction from within of appropriate representations and interpretations.

Learning in the Piagetian sense is therefore seen as an active process in which the learner constructs his or her knowledge through interaction with the environment. The learner is placed in an active role - the child is the architect of his own knowledge (Driver 1983). This has implications for biology and science teachers. The richer the child's environment, the more effective learning is likely to be. Parents and teachers should try to enrich their children's environment to facilitate the development of the intellect.

Ausubel's theory is referred to as the theory of meaningful learning. The basic tenet of Ausubel is : "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel 1968 2nd Ed. 1978 in Novak and Gowin 1984).

Ausubel distinguished between meaningful learning and rote memorisation. Concepts derive meaning through connections or relationships with other concepts and meaningful learning

occurs when new knowledge is consciously linked to relevant concepts or propositions already possessed by the learner. On the contrary, rote memorisation or learning results when new concepts are stored in an arbitrary, non-substantive way. (Novak 1978).

Ausubel regards the term "concept" as an abstract structure of properties that is characteristic of a certain class of objects, events or phenomena. Such a structure may be called the "logic core" of the concept. The "logic core" is normally associated in our memory with a certain "name". A mere name without an associated "logic core" is regarded as meaningless, "the logic core" being the meaning. Beyond the name and "logic core" there is something that makes a concept applicable and memorisable in different contexts - this is called the "associative framework" of the concept. (Schaefer (1979).

Meaningful learning requires a deliberate effort on the part of the learner to relate new knowledge to relevant concepts they already possess. To facilitate this process both teacher and pupil, if they are to proceed most efficiently in meaningful learning need to know the "conceptual starting place". Ausubel illustrated how the concepts and propositions the learner knows play a central

role in meaningful learning. Ausubel, however, has not provided education with simple functional tools to help them ascertain "what the learner already knows". (Novak and Gowin 1984).

Novak developed concept mapping as an educational tool "specifically to tap into a learners cognitive structure and to externalise for both the teacher and learner to see what the learner already knows." Concept mapping as a teaching strategy will be treated later in the chapter. Some contributions to the constructivist view of learning will be considered.

2.3 SOME CONTRIBUTIONS TO THE CONSTRUCTIVIST VIEW OF LEARNING

There are many contributions to the constructivist view of learning. The personal construct psychology of Kelly(1955) in Osborne and Wittrock(1985), has been related to education in general (Pope and Keen 1981) and science education in particular (Pope and Gilbert 1983). The way children develop their own mini theories or personal constructs based on direct experience with the physical world and informal social interactions has been described by Claxton (1983) who suggests the importance of acknowledging and building on

these in science classes. Another contribution to the development of a constructivist approach to learning science has been made by Osborne and Wittrock (1983). Driver and Bell (1986) presented a constructivist view of learning and teaching science which emphasises that since effort is required to construct meaning ultimately the learner is responsible for her or his own learning.

a) GENERATIVE LEARNING MODEL

Osborne and Wittrock (1985) described a model, called the generative learning model, the fundamental premise of which is that people tend to generate perceptions and meanings that are consistent with their prior learning. These perceptions and meanings are something additional both to the stimuli and the learner's existing knowledge. To construct meaning requires effort on the part of the learner and links must be generated between stimuli and stored information.

The generative learning model attempts to illustrate the importance of what learners bring with them to learning situation and recognises the active construction of meanings, which goes on constantly as individuals interact with their environment.

The brain is not a passive consumer of information. Instead it actively constructs its own interpretations of information, and draws inferences from them. The brain ignores some information and selectively attends to other information much more than a "blank slate" that passively learns and records incoming information. (Osborne and Wittrock 1985).

b) ALTERNATIVE CONCEPTIONS

Interest on how pupils learn has led to a number of terms or expressions like, for example, alternative conceptions or frameworks (Driver and Easley 1978); children's science by Gilbert et al 1982. All these terms or expressions signify world views by pupils which do not conform with the ones accepted officially by school science.

Driver (1979) pointed out the connections between a constructivist approach, modern views in philosophy of science and recent developments in science education research pupils, like scientists come to science lessons with some ideas or beliefs already formulated. These beliefs affect the observations and the inferences they draw from them. Pupils, like scientists have construed a view of the world to enable them to cope with situations. Changing the view is not as simple as giving pupils additional experience or sense data. It also involves helping them to reconstruct their theories or beliefs to undergo, the paradigm shifts which have occurred in the history of science. (Gilbert and Zylbersztajn 1985).

"Children's Science" is an expression that was suggested in order to describe those views of the world which do not match those of their scientific counterparts "Scientists science". Gilbert et al (1982) pointed out that teachers should have a greater knowledge of and respect for "children's science". What children think can be developed by causing them to reflect on, and discuss its consequences.

Pines and West (1985) identified two sources of knowledge in the individual. First, there is the knowledge that a child acquires from interaction with the environment, called "intuitive knowledge". This knowledge is influenced by language, culture by other individuals etc. It is the child's own way of making sense of his environment, by observing, tempering, manipulating by his or her interactions with parents, peers etc. The primary characteristic of this knowledge is that it is the child's reality. It is his or her belief system.

The other source of knowledge is formal instruction, discipline knowledge, school knowledge etc. It is someone else's interpretation of the world; someone else's reality. It is "science" it is what the book says or what the teacher says. It is approved by a number of people who are usually older and more highly regarded than the child.

Pines and West's (1985) view of mature conceptual learning is the integration of knowledge from these two sources of information. They also expect four outcomes or situations resulting from the interaction between the two sources of knowledge, namely, conflict, congruent, symbolic knowledge and unstructured situations.

Posner et al (1982) suggested that a pupil will retain the alternative conception if the new material taught seem no more intelligible, plausible or fruitful than the ideas already held.

Helm (1978) reported on the "alarming" prevalence of alternative conceptions in South African schools. Bradley and Stanton (1986) remarked that many pupils fail to make progress in science as a consequence of the retention of conceptual ideas and thinking patterns which are contradictory to those taught by their teachers.

Present day teaching, therefore, should do away with the "tabula rasa" assumption that pupils have no prior conceptions of the topic to be dealt with in the science classroom, or the "teacher dominance" assumption that instructions will wipe out any previously held incorrect notions. "We must be aware of alternative conceptions, be knowledgeable as to the forms they can take and have a positive attitude towards them in that they are the starting points in efforts to remediate them." (Watts and Zylbersztajn 1981).

c) LEARNING AS CONCEPTUAL CHANGE

The "models" or "schemes" referred to earlier are seen to be

structured entities which vary in complexity. An individual's knowledge is not considered as a set of discrete bits of information, but as a series of structures, and, learning involves the development and change of such structure.

Ausubel's (1968) theory of meaningful learning suggested that if a new piece of information or concept can be integrated or subsumed into an existing cognitive structure it is more likely to be accepted. He argued the case for the provision of suitable advance organisers onto which new ideas can be fitted. If, on the other hand, few links can be made to prior knowledge and if the quality of these links is not so high, there will be less chance of the new idea being transferred into long term memory, and hence being retained and becoming useful.

Rumelhart and Norman (1981) in Driver and Oldham (1986) suggested three ways in which cognitive structures may change, namely, accretion - the addition of parts to an existing structure; tuning - involving small modifications to an existing structure and through restructuring - involving major changes in the structuring of knowledge. Strike, Posner, Hewson and Gertzog (1982) suggest that a number of conditions need to be met if conceptual change is to take place. First, there needs to be dissatisfaction with

existing conceptions, and then the new conception must appear intelligible, plausible and fruitful in offering new interpretations.

Pope and Gilbert (1983) suggest four possible outcomes which may occur as a result of a learning programme. Individuals may retain their own perspectives and reject all others; hold onto the original idea but adopt another temporarily, that is, hold the two simultaneously; view their personal models as invalid and discard them, or they may reject both their original perspectives and the ideas put forward by others, suggesting instead an alternative which goes beyond any of them.

2.4 RESEARCH ON SOME PUPILS UNDERSTANDING OF SOME BIOLOGY CONCEPTS

A paucity of research exists regarding high school pupils' understandings and misunderstandings of Biology concepts, for example, children's understanding of inheritance (Engel-Clough and Wood-Robinson 1985); biological adaptation, the world (Osborne, Gilbert and Bell 1983); Life (Brumby 1981, 1982), growth (Schaefer 1979), food webs (Griffiths and Grant 1985) and animal (Bell and Barker 1982); health (Brumby, Gerrand and Auman (1985). Research done in other fields of study, science, in particular has far reaching implications for the

teaching of biology as well. This include pupil's understanding of science concepts like heat, energy, acids and bases, gases and the particulate nature of matter.

Several studies have investigated students' understanding of plant nutrition. Simpson and Arnold (1982) reported on the results of a study of the development of pupils' understanding of the process of photosynthesis and the related biological processes of respiration, breathing and digestion. The information already known to primary pupils before receiving formal teaching in Biology was assessed and the changes effected by teaching were monitored in the secondary school.

The primary pupils' knowledge of food as a source of energy was as revealed by the results, at an elementary level. They appeared to understand that plants need energy to grow and that plants get the energy from their food. However, many of the pupils stated that plants get their food from the soil via the roots. During pupils' S1 (12 - 13) and S11 (14 - 16) years, they received formal instruction on photosynthesis, respiration and digestion. At this level some pupils still considered plants to get their food from the soil. The role of chlorophyll in photosynthesis was also poorly understood. Some pupils' understanding was limited to the role of chlorophyll in terms of converting light energy to chemical energy.

Many students of both age groups confused respiration and breathing. About half the students in each age group, considered respiration to be an exchange of gases between the organism and the environment. Bell and Brook (1984) remarked that to a scientist this is an exchange of gases, or sometimes, breathing. They maintained that to a scientist, respiration is a "cellular chemical reaction releasing energy from food". In addition there were students who felt that unlike the situation in animals, respiration in plants is not continuous or occurs in opposite ways.

Another reported difficulty was the students' understanding of the relationship between food, digestion and energy. One half of the 12-13 year olds and one third of the 14-16 year olds thought that:

- a) energy is obtained from food
- b) digestion is the breakdown of food, and
- c) therefore digestion (not respiration) is the energy releasing process.

The first two statements are acceptable, while the third is not. It would appear that in an effort to link the two scientifically acceptable ideas, the pupils constructed an unacceptable idea.

Most students appeared to think that food is needed for growth. Energy is obtained from food and that energy is

associated with movement or feats of strength. While these ideas are to some extent acceptable, they are scientifically incorrect. Many of the pupils in addition incorrectly thought that the food acquired by plants accretes through the growth of the plant. There appeared to be little understanding that plants used the energy in the food for their own life processes. (Bell and Brook, 1984).

Another study by Simpson and Arnold (1982b) in Bell and Brook (1984) investigated pupils' understanding of the "pre-requisite" concepts for photosynthesis, namely, "living things", gases, energy and food. 11 - 12 year olds; 12 - 13 and 13 - 14 year old pupils were either interviewed or given a pencil and paper test to complete. The findings showed that even pupils who have had two years of science tuition in secondary schools may not understand the concepts of living things, gases, food and energy in a scientifically accepted way.

Roth, Smith and Anderson (1983) described some 11 year old pupils' conceptions of photosynthesis and food for plants before (and after) receiving instruction on the topic. They noted that the pupils they studied had an underlying conception of food as being materials plants take in. This conception was divided into three categories :

- i) things plants need
- ii) all the things plants take in, and

iii) particular things plants take in.
 Bell and Brook (1984) have given a summary of these findings in an adapted form as shown in Table 2.1.

TABLE 2.1

A SUMMARY OF FINDINGS BY ROTH, SMITH AND ANDERSON

Plants and Light		
Issue	Misconception	Goal Conception
1. Plants' need for light	Plants always need light	Plants need light after food in cotyledons is used up.
2. Function of light in plants	Plants need light to live, to grow (nonfunctional explanation based on observations)	Light is used in making food (functional explanation)
Plants and Food		
3. Plants' source of food	Plants take in food from the outside environment.	Plants make their food internally using light, air, and water.
4. Implicit definition of food	Many things could be considered food (fertiliser, sun, water etc.)	Only certain materials that provide energy are truly food; plants get food <u>only</u> by making it themselves.
5. Function of food in plants	Plants need food in order to live, grow (nonfunctional explanation based on human analogy)	Plants need food to supply energy needed for internal life processes (functional explanation)

(adapted from Roth, Smith and Anderson, 1983)

Bell and Brook (1984) reported on aspects of secondary pupils' understanding of plant nutrition. Wandersee (1983) reported on students' misconceptions about photosynthesis. These are the tests adopted in this study and will be discussed in chapter 3.

2.5 SOME TEACHING STRATEGIES

The constructivist view of learning places emphasis on the role concepts or conceptual frameworks play in one's construction of meaning. It is therefore appropriate to consider some teaching strategies which test pupils' understanding of concepts. Particular attention will be paid to concept tests and concept maps.

Gorodetsky and Gussarsky (1986) remarked that the usual tests and examinations used by teachers serve mainly as ranking tools or as measures of the acquisition of knowledge and skills. Tests do not contain the potency for pinpointing the weak and problematic conceptualisations and thus do not normally provide teachers with feedback about the effectiveness of their instruction. Research methodologies on the other-hand use evaluative methods that are capable of supplying the needed information for mapping learning difficulties. Concept tests, concept mapping, spider

diagrams, learning vees, for example, are capable of being used as prescriptive evaluation methods that can lead to change and innovation in teaching.

Nussbaum (1981) remarked that the diagnosis of pupils' misconceptions and the identification of reasons for such misconceptions must be considered the prerequisite for helping the pupils to develop correct "scientific conceptions." Teachers and teacher trainees should be exposed to relevant exercises which will develop their awareness, sensitivity and competency for diagnosing pupil misconceptions.

Concept mapping was developed by Novak. Novak suggested a number of ways of introducing concept mapping to pupils. The following is one of the many ways. Once pupils have acquired the basic skill of the strategy concepts could be selected that are central to understanding the topic to be covered. The pupils could then be asked first to build a concept map relating these concepts and then to add other relevant concepts and link them to form propositions that have meaning. The concepts can be ranked in a specific order if there are significant hierarchical relationships among them.

Alternatively, pupils could be helped to identify a few major concepts in a section or chapter of their text book and use these concepts to begin the construction of a concept map. The pupils can then move easily and identify other relevant concepts and add these to form their own concepts maps. Meaningful use of concept maps as a preinstructional tool is best arrived at by first, giving careful thought to the choice of key concept labels selected as the base for the map. Second, helping pupils to keep searching their cognitive structures for relevant concepts. Third, helping pupils construct propositions between the concepts provided and the concepts they know by helping them to choose good linking words. Fourth, helping pupils to discriminate between specific objects or events and the more inclusive concepts these events or objects represent. This will serve the important purpose of conceptual growth.

Concept mapping can be used to show relationships between ideas. It can be used to extract meanings from textbooks; laboratory, studio and or field studies. It can be used as a short hand for taking notes. It can also be used in planning a paper or exposition. Concept mapping has been researched on by a number of educationists. Charles Ault (1985) has said about concept mapping:-

- i) concept mapping leads students away from rote learning and toward true understanding of concepts and their relationships.

- ii) concepts signify patterns in events and connect experiences that are otherwise unrelated.

A concept map depicts hierarchy and relationships among concepts. It demands clarity of meaning and integration of details. Mapping exercises require one to think in many directions and to switch back and forth between levels of abstraction.

Concept maps can be used by science instructors, students, educational researchers and teacher educators in:-

- Lecture preparation
- Curriculum planning and evaluation
- Class discussions
- Laboratory reports
- Text study
- Examination - essays could be replaced by concept maps
- Computer assisted instruction
- Knowledge representation
- Interview analysis
- Lesson plans

Concept mapping is one of the strategies for addressing the problem of why pupils learn so little. If used properly concept mapping enhances opportunities for meaningful learning.

Research work on concept mapping include among others, concept mapping in College Science Teaching by Arnaudin et al (1984); Lehman, Carter and Kahle (1985) reported on concept mapping and Vee mapping - results of a field study with Black High School Students. Malone and Dekkers (1984) reported on concept map as an aid to Instruction in Science and Mathematics.

The researcher feels that concept test and concept maps are useful strategies in testing pupils understanding of concepts. Since English is a second language, pupils tend to memorise the work presented to them without real understanding of what it is all about.

Through use of concept tests and concept maps a teacher may be in a better position to assess pupils understanding of concepts. The pupils on the other hand may also be in a better position to organise their thoughts and experiences in a meaningful way. Team or group work could prove fruitful as pupils are free to express their views to their peers, they are free to argue, they correct themselves and may come up with good concept maps. Concept mapping can develop a competitive spirit among pupils and hence creativity which may lead to meaningful learning.

The researcher thinks that these teaching strategies are worth giving a try.

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

A number of research methods were employed to collect data. These included questionnaires, concept tests, interviews and concept maps.

3.2 QUESTIONNAIRES

Questionnaires were sent to Std 10 pupils in 15 schools selected randomly from the Central Region of Transkei. The aim of the questionnaire was to identify some of the problems experienced by senior secondary school pupils in some aspects of Biochemistry and possible causes.

The questionnaire (Appendix 1) consisted of 21 items. Items (1-8) required some basic details of pupils such as the name of the school, sex, age, class, whether the pupil were doing Physical Science in Std 10 or not, whether the pupils did Physical Science in Std 8 or not, the symbols obtained in Std 8 in both Physical Science and Biology.

Item 9 consisted of a list of Biochemistry topics as laid down by the current syllabus. The pupils were required to mark 3 topics they found easy and 3 they found difficult. In

item 10 pupils were required to explain why they found the 3 topics easy and in item 11 why they found the 3 topics difficult. Items 12, 13, 14 and 15 pertained to language. In item 16 the pupils were presented with a list of some of the possible experiments in Biochemistry. They were then required to mark the experiments that were done in their schools. They were required to mark with a T those done by the teacher and with a P those done by the pupils in their classes. In items 17 they were required to indicate the experiment they liked best and in 18 the reason for liking the experiment.

In item 19 pupils were asked if they wished to study Biochemistry at University level and in 20 and 21 were required to give reasons for wanting to study Biochemistry at University level or for not wanting to study it any further.

Although questionnaires were used to collect data the researcher is very much aware of the unreliability of information gained from questionnaires. Questionnaires are useful tools for gaining information quickly but one has to be very cautious with the information. From my experience as a researcher, pupils do not take them seriously, information from some pupils concerning the experiments, for example, is contradictory. Some pupils misinterpret questions.

Because of the limitations or shortcomings of the questionnaires some other research methods were used to collect data.

3.3 INTERVIEWS

Interviews were conducted with Senior Secondary School teachers; subject committee members; lecturers from the University of Transkei; subject inspectors; subject advisers and lecturers from the Transkei Teachers In-service College and some pupils.

The aim of the interviews was to determine the problems experienced by both pupils in Biology. An interview has an advantage over a questionnaire because the interviewer communicates directly with the interviewee or respondent. In an interview situation one has a chance of restructuring the question if the respondent does not understand or gives an unexpected response. The structured interview has an added advantage of giving the respondent a list of questions to be asked in advance so that he/she can have enough time to go through the questions before the interview.

Structured as well as unstructured interviews were conducted. Structured interviews involved twenty respondents namely, eight subject committee members, four lecturers from the University of Transkei (2 of whom were examiners for the

the higher grade and standard grade Matric Biology), 2 lecturers from the Transkei Teachers' In - Service College 1 subject adviser, 1 subject inspector and 5 senior secondary teachers.

As a lecturer at the Transkei Teachers In-Service College the researcher had a chance of discussing teacher problems with the Std 8, 9 and 10 teachers who attended courses in 1988 and 1989. Interviews with the majority of teachers were therefore unstructured.

Some of the questions asked in the structured interviews included the following:-

- which sections are perceived to be difficult in the Matric Biology Syllabus?
- Are the sections difficult for the pupils or teachers or both?
- Do you consider Biochemistry to be one of the difficult sections?
- If you feel that Biochemistry is one of the problem areas can you give reasons why you feel that this area is a problem?

3.4 CONCEPT TESTS

Research by Bell (1984), Wandersee (1983) and others have shown that photosynthesis is a difficult concept to pupils. Johnstone

and Mahmoud had also identified photosynthesis as a problem area. The researcher decided to administer the concept tests of Bell and Wandersee to see if they were relevant in Transkei. Further, the administration of the concept tests was a result of interest in the topic and a result of the questionnaires. The teachers had identified photosynthesis as a problem area, but the pupils identified photosynthesis as one of the easy topics - in fact photosynthesis ranked high as an easy topic.

2 concept tests on photosynthesis were administered to Std 10 pupils at different times of the year. There is an amount of overlap in the two concept tests on photosynthesis used. One test was administered in Britain and the other one in the United States of America. The researcher wanted to determine whether the pupils could identify the concept in different situations. However no attempt was made to match pupil responses for the two concept tests. The researcher is aware of the importance of matching the pupil responses but time was a limiting factor.

The concept test by Bell was administered to 15 year old British pupils. The researcher wanted to find out how Transkei Senior Secondary School pupils would fare and whether they hold similar misconceptions. British pupils are native speakers of English and Transkei pupils are taught through a second language. Strevens (1976) remarked

that language problems are encountered by science educators and learners of science when the vehicle of instruction is not their mother tongue.

Bell (1984) reported on aspects of secondary students understanding of plant nutrition. Bell wanted to find out the kinds of ideas some secondary school students have about aspects of plant nutrition. The following aspects of plant nutrition were investigated:

- the extent to which pupils understand autotrophic nutrition in green plants.
- the extent to which pupils understand the roles of light, chlorophyll, and raw materials in photosynthesis.
- the pupils' conceptualisation of the relationship between food, energy and maintenance of plant metabolism.

Information was obtained by analysis of written responses given by 15 year old students to three questions, each requiring the application of ideas about plant nutrition in a different context. About 300 responses to each of the questions were analysed in order to describe the kinds of ideas used by the pupils. The sample was representative of the 15 year old population. In addition, a further 25 pupils were asked to respond orally to three questions in an interview situation.

Bell's test was adopted and administered to Std 10 pupils in 15 schools chosen randomly from the Central region of Transkei. The test was administered to investigate the same aspects that were investigated by Bell. 308 pupils answered the test. The questions are shown fully in Appendix 11.

QUESTION 1 HAY-TODAY

The question read as follows:

A farmer cut his meadow for hay. He noticed that the grass he cut was green, but the stalks left were yellow. How do you explain this?

To cater for second language pupils "hay" was simplified as "feeding grass" which does not appear in the original text.

QUESTION 2 VILLAIN

In a science fiction book, a villain threatens to spray the countryside with a chemical that destroys chlorophyll (the green substance in plants).

What effect will this have on plant life? Explain your answer as fully as you can.

Villain was simplified as "wrong doer".

QUESTION 3 GROW TREE

A small tree is planted in a meadow. After 20 years it has grown into a big tree, weighing 250kg more than when it was planted.

Where do the extra 250kg come from? Explain your answer as fully as you can.

Bell's responses will be discussed with Transkei pupils' responses in Chapter 4.

The second concept test called photosynthesis concept test (PCT) was adopted from a research conducted by Wandersee and edited by Helm and Novak (1983). Wandersee conducted a cross-age study on students' misconceptions about photosynthesis.

The photosynthesis concept test (PCT) was used to detect the misconceptions of students. It consisted of 12 tasks, each involving an experiment, a phenomenon or a situation that calls for student response, or to complete drawings in order to simulate what occurs in a clinical interview. A number of sub-concepts considered necessary to understanding the major concept of photosynthesis were identified. Wandersee subsequently generated 12 test tasks considered appropriate for the population to be tested.

The PCT was adopted and administered to Std 10 pupils to see how they would fare. No cross age study was undertaken as was the case with Wandersee.

Wandersee based his study on Ausubels' (1968) assimilation theory of cognitive learning and its subsequent elaboration by Novak (1978). The problem was to detect common misconceptions students harbour about the concept of photosynthesis and to investigate whether their conceptions change as they are exposed to additional information about photosynthesis in progressive higher grades. Students from 49 schools and colleges in nine states wrote the PCT supervised by their regular classroom instructors. The sample consisted of pupils in elementary school (grade 5); Junior high school (grade 8); senior high school (grade 11) and college.

The PCT was constructed to "probe students conceptions regarding selected aspects of the photosynthesis concept." The following aspects were considered in the study.

- a) the basic function of soil in plant growth and photosynthesis
- b) the basic role of photosynthesis in the carbon cycle
- c) the basic roles of the leaf and light energy in photosynthesis
- d) and the primary source of food in green plants.

The responses of pupils in the four categories were analysed and there were significant differences between the four class levels at 0,01 level. All the twelve tasks were analysed according to the four grade levels. The results revealed that with few exceptions students concepts of photosynthesis continued to change as they moved through the educational system. A number of naive ideas and misconceptions about how plants make food were uncovered.

Wandersee (1983) felt that some societal practices encourage misconceptions about how plants live. For example, garden shops sell fertilisers labelled "plant food" and "weed and feed"; florists talk about "feeding" their green house crops and mothers tell their children to "give the plants a drink."

It is felt that lessons about photosynthesis in school are sometimes linked to inappropriate and invalid subsuming concepts. Teachers should therefore assist the child in identifying the unscientific concepts and in correcting the misconceptions. If that is not done "integrative reconciliation" (new learning that results in explicit deliniation of similarities and difference between related concepts), will not occur.

The researcher had problems with some questions in the PCT. These are problem 2 task 3 and problem 4 task 8. The problems will be discussed further in Chapter 4.

Concept mapping was administered to 63 pupils doing Std 10 from the same school. The pupils were introduced to concept mapping while in Std 9. Some teachers in the same school had been using concept mapping as a teaching strategy - biology, physical science and English.

The tasks given included providing pupils with a list of related concepts and asking them to draw a concept map to show their understanding of a particular topic. As they were getting used to the strategy, they were then required to draw concept maps to summarise lessons or to test their understanding of a topic to be taught to find out their prior or existing knowledge or alternative conceptions. Concept maps drawn included concept maps on organic compounds, proteins and photosynthesis.

Concept mapping as a teaching strategy was also introduced to teachers attending courses at the Transkei Teachers In-service College. Teachers who attended the Std 8, 9 & 10 courses in 1988 and 1989 were introduced to concept mapping as a teaching strategy. They were given tasks that tested their understanding of, for example, mitosis, meiosis, protein synthesis, inheritance and variation, population regulation by homeostatic control and the relationship between lymph and tissue fluid.

Teachers who had no problems with the content (subject matter), mastered the strategy faster than those who had problems. It was easier for the highly qualified teachers to see the relationship between and among concepts. Some teachers perceived concept mapping to be a valuable tool for assessing the effectiveness of their instruction. Others, however, showed resistance and reluctance in trying to implement the strategy. They felt that concept mapping would be very difficult for the pupils, and because they are faced with large classes it would be very difficult for them to implement the strategy.

CHAPTER 4

4. DATA PRESENTATION AND ANALYSIS

4.1. RESPONSES TO PUPIL QUESTIONNAIRES

350 questionnaires were sent to 15 schools selected randomly from the Central Region of Transkei. The questionnaires were administered to Std 10 pupils. 308 pupils responded to the questionnaires. Of the 308 pupils, 124 were boys and 184 were girls.

The ages of the pupils are shown in Table 4.1

TABLE 4.1

AGES OF PUPILS (n = 308)

AGE RANGE	NO. OF PUPILS	%AGE
13 - 15 years	6	1,9
16 - 18 years	132	42,9
19 - 21 years	131	42,5
Above 21 years	39	12,7
TOTAL	308	100,0

The ages of pupils ranged from 13 years to above 21 years. 6 pupils fell in the age range of (13 - 15) years; 132 in the

(16 --18) year range; 131 in the (19 - 21) year range and 39 in the (above 21 year) range. 55,2% of pupils reflected in the table are older than 18 years. This may be due to many factors. In some rural areas the schools are not easily accessible to pupils. Pupils have to walk long distances to school. As a result of this they start schooling at an age later than the normal 6 years in urban areas. Some of the pupils are teachers (HPTC) who have gone back to school to upgrade their qualifications. Some pupils, because of financial problems were compelled to go to work after passing Std 8, and have returned to school to further their studies.

Of the 308 pupils who responded to the questionnaires, 157 did both Physical Science and Biology in Std 10, 210 did Physical Science in Std 8 and 98 did not do Physical Science in Std 8. For quite some time in Transkei schools, Std 8 pupils had to do seven subjects. The pupils therefore had to drop one subject in Std 9 as they have to do six subjects. It was only in 1984 that the pupils had to do six subjects in Std 8, and Physical Science became optional. The Biology teachers are therefore faced with pupils who have different physical science or chemistry background. This difference in chemistry background may affect the performance of pupils in Biochemistry.

Table 4.2 gives an analysis of Std 8 Physical Science symbols or results.

TABLE 4.2

ANALYSIS OF PHYSICAL SCIENCE RESULTS (n = 210)

SYMBOL	%	NO. OF PUPILS	%AGE
A	80+	3	1,4
B	70 - 79	6	2,9
C	60 - 69	31	14,8
D	50 - 59	69	32,9
E	45 - 49	70	33,3
EE	40 - 44	4	1,9
F	33 - 40	15	7,1
G	below 33	1	0,5
No response		11	5,2
TOTAL		210	100%

About 50% of pupils obtained at least a D and higher symbols. The majority however obtained D and E.

TABLE 4.3 gives an analysis of Std 8 Biology symbols.

TABLE 4.3

ANALYSIS OF STD 8 BIOLOGY SYMBOLS (n = 308)

SYMBOL	NO OF PUPILS	%AGE
A	5	1,6
B	13	4,2
C	80	26,0
D	134	43,5
E	55	17,9
EE	-	-
F	9	2,9
G	1	0,3
No response	11	3,6
TOTAL	308	100%

Comparing the Biology and Physical Science Symbols, the Biology symbols are one symbol higher. About 75% of pupils scored above D compared to 50% in the case of Physical Science. But even in Biology the mode is a D symbol, which is not a good pass for Std 8 Biology. Symbol E is not a recommendation at all for pupils to continue with Biology at matric level. Even those who got F are still going to do Biology at Matric level and some of them at Higher Grade.

Pupils were presented with Biochemistry topics and were asked to mark 3 topics they considered to be easy and 3 they considered difficult. Table 4.4 gives the responses of easy topics in order of frequency.

TABLE 4.4

RESPONSES TO EASY TOPICS (n = 893)

TOPIC	NO OF RESPONSES	%AGE
Photosynthesis	188	21,1
Chemical processes of digestion	159	17,8
Enzymes and Co-enzymes	133	14,8
Cellular respiration	104	11,6
Relevant functions of water and proteins	91	10,2
Biological compounds and nutrients	77	8,6
Nucleic Acids	68	7,6
Chemical composition of protoplasm	45	5,0
Protein synthesis and gene mutation	28	3,1
TOTAL	893	

Since the questionnaire was administered to 308 pupils, and each pupil was requested to mark 3 topics he/she considered easy, the expected number of responses was 924. From the table the total number of responses is 893. This is due to the fact that some pupils marked 2 or even 1 topic instead of 3 topics.

Table 4.5 gives the responses for difficult topics.

TABLE 4.5

RESPONSES TO DIFFICULT TOPICS (n = 893)

TOPIC	NO OF RESPONSES	%AGE
Protein synthesis and gene mutation	173	19,4
Cellular respiration	119	13,3
Chemical composition of protoplasm	116	13,0
Biological compounds and nutrients	115	12,9
Nucleic Acids	114	12,8
Enzymes and Co-enzymes	72	8,1
Photosynthesis	63	7,1
Relevant function of water and proteins	61	6,8
Chemical processes of digestion	60	6,7
TOTAL	893	

There are inconsistencies in the pupils' responses. One would expect the responses to easy topics and the responses

to difficult topics to be the inverse. Protein synthesis ranked high as a difficult topic and least as an easy topic, that is 173 responses (19,4%) for difficulty and 28 responses (3,1%) for easy. Although Photosynthesis ranked high as an easy topic, that is 188 responses (21,1%); there are still 63 pupils (7,1%) who consider photosynthesis to be difficult. Chemical processes of digestion ranked least as a difficult topic and second as an easy topic.

In addition to marking the easy and difficult topics pupils were required to give reasons for considering some topics easy and reasons for considering some topics difficult.

Responses to reasons for difficult topics were categorised as follows:-

1. Lack of chemistry background
2. Difficult terminology or Biotechnical terms.
3. Difficulty in dealing with abstract concepts.
4. Lack of interest/Negative attitude
5. Lack of Laboratory Equipment/Practical work
6. Some topics not taught.

1. **Lack of chemistry background**

The following are some of the responses that showed a lack of chemistry background. (Number in brackets refer to topics listed on page .

- I did Physical Science up to Std 7. Some of the questions set in Biochemistry need Std 8, 9 & 10 chemistry.

- Topics (2,4,5) are difficult because I have never done Physical Science in Std 8, 9 & 10.

2. Difficult terminology of biotechnical terms
The following are some of the responses encountered.

- Biochemistry involves complicated terminology.
- There are many keywords to use and know and are similar for different things, for example, ADP and ATP; NADP and NADPH so I get confused.

3. Difficulty in dealing with abstract concepts.

Examples of responses are given below:

- They are difficult because we cannot see them happening; we are made to believe that they do happen (4,5,9).
- Too abstract (5,8,9) - I try to read them but after reading them I cannot tell what I was reading about.

4. Lack of interest / Negative attitude

- I have to memorise them, so I do not feel happy when reading them.

The terminology is very boring, for example, enzymes are proteins, enzymes are specific as regards function, substrate etc., therefore they have to be learned off one by one.

5. Lack of laboratory equipment / Practical work

- I only read about cells and starch tests from the textbook, without having to use a microscope to see the components of a cell or to perform some starch or protein tests.
- Biochemistry is difficult because it is not taught in a way that a student can easily understand - there is no laboratory equipment in the school.

6. Some topics not taught

- (3,4,8) are difficult because they have not been taught.
- Some of the teachers do not explain clearly - they just read from the textbook.

Responses to reasons for easy topics were categorised as follows:-

1. Correlation between subjects
2. Continuity in the syllabus
3. Teacher competence
4. Relevance/Clear/Simple
5. Other responses

1. **Correlation between subjects**

- There is correlation between Agricultural Science and Biology (5,7,9)
- There is an overlap of what I do in Physical Science (Organic Chemistry) and Biochemistry especially organic compounds.

2. **Continuity in the syllabus**

- (7,8,9) are easy because they are the continuation of the syllabus I started in Std 5.
- Continuation of the work done in lower classes (1,2,3)

3. **Teacher competence**

- the teacher taught them well.

4. **Relevant / clear / simple**

- They are relevant, clear and understandable (6,8,9)
- These topics have no complications. They are clearly defined and easy to understand (7,8,9)

5. **Other responses**

Some reasons could not be used, for example,

- they are easy because they are easy to understand; they are difficult because they are difficult to understand.

Some pupils admitted having no reasons for either considering some topics easy or difficult.

Items 12, 13, 14 and 15 of the questionnaire pertained to language used by textbook writers and the language of the teacher. Only a few pupils commented on the difficulty of the language used in textbooks or that of the teacher. Those who did expressed their grievances against their teachers. They are against teachers who do not explain in Xhosa.

The following are some of the responses.

- when she talks she rolls her tongue and does not use vernacular.
- our teacher is a foreigner - it is very difficult to communicate with him.

The following responses point to the teacher attitudes towards pupils and the effect these may have on the teaching - learning situation.

- Our teacher has no patience at all with us - general students - it is therefore difficult for us to ask questions because she always labels us stupid.
- Our teacher is always shouting at us - even if one does not understand something, we prefer to keep quiet.

The pupils were presented with a list of possible experiments in Biochemistry as shown in Appendix 1. They were required to mark those experiments that were done or demonstrated by their teachers and those done by them. Results indicated that experiments generally are not done. About 30% of the pupils did not respond. Those who did, were questionable as pupils from the same school responded differently. Some experiments that were performed in some schools, from the pupils'

responses included tests for starch, fats and proteins and experiments on photosynthesis, that is, 9(a), 9(b), 9(c) and 9(d).

Iodine test for starch appeared to be the most popular experiment as many pupils appeared to like it. Even those pupils who did not mark any experiment done either by the teacher or themselves indicated the experiment they liked best. The following are some of the reasons for liking the iodine test for starch:

- It is very understandable, perhaps it may be that I had done it in Std 7.
- It is because it does not need many apparatus, it is simple, I see the results and they satisfy me.

Experiment to determine whether chlorophyll is necessary for photosynthesis was the second most liked experiment. The reason for liking this one included the following:

- It is because I would like to know how a plant breathes.
- I like those dealing with chlorophyll in the leaves, that is, photosynthesis experiments because they deal with the things I see in nature.

The reasons for not conducting or performing experiments may be varied. This may be due to lack of laboratory equipment, teachers not competent to do the experiments even if the equipment is available, teachers not able to improvise, teachers being unable to equip the laboratory even if the funds are available, laziness on the part of the teacher and so on.

The following is an extract from a report by the then subject advisor for Biology in connection with laboratory equipment:

During the check and guidance visits to the schools, I discovered that up to 80% of the schools in the country are without even the basic equipment necessary for the effective teaching of Biology." The pupils who claimed to have performed the iodine test for starch in Std 7 may be honest because the Science Education Project (SEP) equipment is used by a large number of schools in Transkei, that is, Junior Secondary Schools.

To the question of whether pupils wanted to study Biochemistry at University level, 35% of the pupils wanted to study Biochemistry at University level, 42% did not want to study it any further and 23% did not respond. Some pupils may have expressed their desire to pursue university education although they know that they will never get there, because of their abilities, financial problems and so on. Pupils who are going to follow careers or fields other than science, medicine or paramedical courses do not have to do Biochemistry any further.

One has to be very careful therefore in dealing with information gained from questionnaires as some pupils do not take them seriously.

Reasons for wanting to study Biochemistry at University level were placed in four categories, namely,

- a) Further knowledge
- b) Further studies

- c) Easy/relevant
- d) Other responses(no response or no reason given)
 - a) Further knowledge
 - I like Biochemistry because I want to get more knowledge about it.
 - Biochemistry opens up one's mind.
 - b) Further studies
 - I like to study Biochemistry because I want to do B.Sc at University, so without Biochemistry you cannot do B.Sc.
 - c) Easy/relevant
 - It is relevant to everyday life.
 - I like it because you see what really takes place by means of experiments.
 - d) Other responses
 - I like Biochemistry, although I do not really understand it.
 - I like the section on Biochemistry.

The reasons for not being keen in studying Biochemistry at University level were placed in five categories, namely,

- a) Difficult to understand
- b) Lack of Physical Science/Chemistry or Mathematics background
- c) Lack of interest
- d) Don't see the need
- e) Other responses.
 - a) **Difficult to understand**
 - If I do not understand Biochemistry now, I cannot understand it at University.

- If I study it any further it will give me more difficulties.

b) **Lack of chemistry or mathematics background**

- Biochemistry needs someone who knows physical Science and also Mathematics
- I am doing General so I do not have full understanding of Biochemistry.
- I cannot manage to study Biochemistry without Chemistry.

c) **Lack of interest**

- I do not like it

d) **Don't see the need**

- My career does not need it
- I want to go to work I am not in a position to go to University.

e) **Other responses**

Mainly no response or no reason given, for example:

- I do not have a reason.

4.2 INTERVIEWS

Interviews were conducted with Senior Secondary School teachers; Biology subject committee members; lecturers from the University of Transkei; subject inspectors; subject advisers and Lecturers from the Transkei Teachers' In-service College, and some pupils.

Structured as well as unstructured interviews were conducted as stated in Chapter 3. As a Lecturer at the Transkei

Teachers' In-service College, the researcher had a better chance of meeting Std 8, 9 and 10 Biology teachers. From interviews with teachers, and listening to them discussing their problems, we were in a better position to get to know more about their problems.

The following is information obtained from the structured interviews:-

All persons interviewed perceived Biochemistry and other areas of the Matric Biology syllabus difficult for the pupils and some teachers. Teacher problems or details will be considered first. The responses were summarised as follows:

- If a teacher holds a post secondary diploma in Education it may be difficult for him to teach sections like Genetics and Protein synthesis.
- The sections are certainly difficult for pupils to understand.
- Most teachers teaching Biology Senior Certificate are underqualified, i.e Matric and profession; BA and profession (no science).
- Some qualified teachers glue themselves to prescribe textbooks, or do not teach Physical Science at all levels and therefore have no background of the extent of Physical Science at Std 8 level. They fail to bridge the gap.

- Some teachers apply memorisation.
- Some teachers do not attend in-service courses or do not read recent publications on the subject.
- Biochemistry is a problem area since teachers who teach it, as students, were never properly taught the section or it was never even taught to them, even though it was prescribed because the teachers who taught them knew nothing about Biochemistry, and they did not even attempt to grasp basic concepts required by the syllabus.
- Poor academic background of teachers especially in Chemistry
- Teachers attitudes towards Chemistry
- Failure to realise its relevance to Biology

Responses regarding pupils included the following:-

- Biochemistry includes deep understanding of Chemistry far above Std 8 level
- Most students doing Biology at Senior Certificate do not study Physical Science at Senior Certificate level at all.

- In schools where students study Biology and Physical Science at Senior Certificate, Biochemistry is taught in most schools before they study Organic Chemistry which forms the last chapter of the Std 10 Physical Science.
- Pupil's poor background knowledge of Chemistry.
- Pupil's attitudes towards science (Chemistry).

Some problem areas in biochemistry as revealed by Trinset staff and some lecturers who conducted a course in March 1987 for Biology teachers on Nucleic Acids, Carbohydrates, protein and lipid metabolism, photosynthesis, Respiration, Enzymes and Co-enzymes and inorganic chemistry are summarised as follows:

- Rule for naming organic molecules.
- Differentiation between lipids and fats.
- Differentiation between saturated and unsaturated fatty acids.
- Esterification.
- Open chain forms of monosaccharides and identification as well as construction of ring forms from open chain forms.
- Hydrogen bonding
- Co-enzymes
- Photosynthesis, i.e., breakdown of water into hydrogen

and oxygen." Tendency is to memorise this section with no in-depth explanation."

- Cellular respiration

Lecturers interviewed remarked that Biochemistry (and other areas of Biology) poses problems to first year University Students. One Lecturer commented:

I have dealt with the Biochemistry section of the Zoology I syllabus, with first year students. They arrive at University with negligible or no knowledge of the Biochemistry section, though it is prescribed for the matric syllabus. They even struggle further at University to comprehend tuition on organic compounds and genetics."

Some bright pupils do not experience problems at university.

SUGGESTIONS

The following is a list of suggestions by the persons interviewed and teachers attending courses at the Transkei Teachers' In-service College.

- Teacher upgrading
- Systematisation of topics in the teaching of Biology, i.e. - carbohydrates, protein and lipid metabolism should be taught under nutrition in the plant kingdom, cellular respiration should be taught under respiration in plant and animal kingdom etc.
- Continuity of concepts in relation to Std 9 & 10 syllabus for example, discussion of the functions of nucleus in cells should be linked directly with cell activities, that is, replication as in multiplication,

protein synthesis, lipid formation.

- Need for suitably qualified teachers
- Practical work should be emphasised.
- In-service courses for the ill-prepared or poorly qualified teachers.
- Chemistry should be a prerequisite for Biochemistry.
- Relationship between theory and practical work should be emphasised.
- Biochemistry to be introduced as a course for teacher trainees both at Teacher Training Colleges and Universities.
- Concepts should be thoroughly explained especially that students doing Biology at Senior Secondary School level have not been introduced to a high level Physical Science course to understand the organic compounds applied in Biology. Organic Chemistry should, therefore, be introduced at Std 8 level.
- Syllabus should be explicit in elaboration, and thus leave no doubt about the extent of each topic addressed at the schools.
- Teachers who have been properly taught Biochemistry or Biology should be encouraged to teach at the first year of Senior Secondary School (Std 8) so that they can lay

the proper foundation. Students who go through this set up are not likely to be confused by teachers in higher classes. They will need to challenge any teacher in higher classes who tends to introduce misconceptions.

- Teachers attending in-service courses should give a compulsory feedback to teachers of their respective regions on their return from such courses.
- Highly qualified teachers or experienced teachers with the know-how should help other teachers in the teaching of the subject or section which is a problem area. This could be organised through regional subject committees. Schools should invite people/lecturers who have the information to address their students or teachers of a given region.

Teachers who do not see the relevance of Biochemistry to Biology should be made aware that Biochemistry is necessary for better understanding of, for example, plant and animal physiology.

Further interviews with teachers revealed that, some teachers were never trained to teach Biology, but were forced by their principals to teach it. Some of these teachers become enthusiastic but others are just at sea. It is very common to come across a teacher who has never handled a microscope, cannot mount a slide and cannot focus.

The next part of this chapter will be analysis of data obtained from the concept tests that were administered.

4.3. RESPONSES TO CONCEPT TESTS

Responses to Bell's test will be considered first.

QUESTION 1. "HAY - TODAY"

An accepted scientific response, according to Bell, would contain the following ideas:-

- the pigment chlorophyll is responsible for the green colouring in the grass.
- in the absence of light, no chlorophyll is manufactured by the plant.
- the blades of grass are at the top of the plant, are exposed to sunlight, and are therefore green.
- the stalks of the grass are at the bottom of the plant, are shielded from the sunlight and are therefore yellow.

In response to the "hay-today" question, four main categories of answers were identified by Bell.

The categories are:-

1. Responses including components of the accepted answer.
2. Responses including alternative ideas about plant nutrition.

3. Responses that include alternative explanations for the colour difference.
4. Other responses

Bell's categories will be used in analysing Transkei pupils' responses to the three questions.

Table 4.6 is a summary of Bell's findings and the researchers findings.

TABLE 4.6

RESULTS FOR HAY-TODAY QUESTION FOR BELL'S PUPILS AND
TRANSKEI PUPILS

CATEGORY OF RESPONSE	BELL'S FINDINGS n= 344	TRANSKEI PUPILS n= 308
Responses including components of the correct answer	30%	60%
Responses including alternative ideas about plant nutrition	7%	3%
Responses that include alternative explanations for the colour difference	42%	27%
Other responses	21%	10%

Responses in each category of responses will now be considered.

1. Responses including components of the accepted answer

This category according to Bell incorporates responses in which the relevant accepted scientific ideas were given. The responses in this category of responses did not necessarily include all four main ideas; most students gave responses with only one, two or three ideas. Transkei pupils' responses were analysed in the same light. About 60% of the responses fell in this category. Responses included:-

a) **Responses involving exposure to light**

About 25% of responses were placed in this category, for example,

- the stalks were yellow because they were not exposed to sunlight.
- the grass was too long. Consequently the stalks below did not get sunlight.

b) **Responses involving chlorophyll**

15% of the responses contained ideas about chlorophyll, for example,

- because of the presence of chlorophyll the grass was green and the stalks were yellow because of lack of chlorophyll.
- this is because the yellow stalks have lost the chlorophyll which makes the grass to be green.

(c) **Responses involving sunlight and chlorophyll**

12% of the responses contained ideas about sunlight and chlorophyll as in the following examples:

- the grass is green because it contains chlorophyll, the grass is exposed to sunlight.
 - the one which was green was exposed to sunlight so it had chlorophyll and the stalks which were yellow were not exposed to sunlight they had no chlorophyll.
- d) Responses involving radiant energy

8% of the responses mentioned radiant energy only. Examples are given:

- the stalks of the grass do not find the radiant energy so they become yellow.
- I can explain it as the absence of sunlight. The sunlight reached only the exposed part of the grass. The chlorophyll cannot function in the absence of light energy from the sun.

2. Responses including alternative ideas about plant nutrition.

A very small percentage about 3% of the responses were classified in this category. The following are some of the responses.

Because soil is lacking nitrogen and the soil is infertile, there is lack of nutrients.

He hates the two colours in the grass and he knows the grass which is green at the top has no nutrients for his cattle because the food is coming from the roots.

the grass now has no roots planted in the soil and therefore no food and no water.

3. Responses including alternative explanations for the colour difference.

About 27% of the responses were classified in this category. The following ideas were encountered.

a) **Responses involving heat**

- It can be explained as that the upper grass get the chlorophyll soon and the stalks left yellow has no chlorophyll but heat that is over.

b) **Responses involving loss or lack of leaves.**

- There is no chlorophyll since there are no leaves.
- The stalks became yellow because there was no photosynthesis taking place as there were no leaves because photosynthesis takes place in the leaves.

c) **Responses involving cutting of the grass**

- The chlorophyll loses its green colour when the plant is being cut. That is why the grass is becoming yellow.

The chlorophyll responsible for the green plant is not functioning for the hay has been removed from its natural environment and thus activities like photosynthesis, respiration and such cannot continue.

d) **Responses involving death and loss of chlorophyll.**

- chlorophyll being lost, the grass dried. Chlorophyll lost its green colour and all the cells died.
- the grass dried and turned yellowish. Chlorophyllous cells died out due to lack of water, mineral salts and CO₂ which are essential for the maintenance of green colour of leaves.

e) **Responses involving cutting of the grass and death.**

- The grass he cut was green because it was living but after he cut it, the stalks left were yellow because they have no life. So they are the non - living plants. (everyday experience, but irrelevant to the question).

f) **Responses involving the yellow colour as resulting from death.**

- The yellow colour of the stalks is caused by the absence of chlorophyll. Since there are no leaves with green pigment for the manufacture of food for feeding the plant, the plant died as a result the yellow colour appeared.

g) **Responses including lack of major nutrients and too much water.**

- the stalks were yellow because of lack of major nutrients and too much water.

h) **Responses involving sun.**

- The grass was green because in the soil it gets water and some mineral substances to make it green all the time. The stalks were yellow because of the sun.

i) **Responses including lack of water.**

- The yellow stalks are caused by not enough water to the grass. So that means there has been no photosynthesis occurring.

j) **Conversion of chlorophyll to chromoplast.**

- chlorophyll is converted into chromoplast by the sunlight.

k) **Phototropism**

- The stalks are not in direct contact with sunshine therefore phototropism does not take place properly.
- Plants grow towards light and they produce hormones (auxins) to initiate their growth.
- If a plant is cut below the region where auxins are produced, no growth no photosynthesis, the leaves turn yellow.

l) **Colour change due to age.**

- When the grass grows up, the older leaves were rotten in the stalk and new green leaves were formed so those older leaves turned to a yellow colour and covered the stalk.

m) **Atmospheric gases.**

- By removing the green grass, the farmer is making a mistake because the green grass absorbs light during photosynthesis and it uses CO_2 and releases oxygen to the atmosphere. So it plays an important role in nature because we breathe in oxygen and give off CO_2 .

4 Other Responses

About 10% of the responses were placed in this category of responses. Responses included mainly no responses or responses which could not be used or classified as in the following examples:

- i) he must continue cutting and grow another crop for he has already cut the stalks.
- ii) a teacher is teaching his pupils in a good way such that they seem to understand. When it comes to writing an exam they nearly all fail.

A number of pupils from the same school gave the same response as (ii) and it is not clear whether this reflects a misunderstanding about the question.

QUESTION 2. VILLAIN.

An accepted scientific response according to Bell, would contain the following ideas:

- with no chlorophyll, the plants would be a yellowish / white colour.
- with no chlorophyll, photosynthesis cannot occur.
- the plants would be unable to manufacture their own food.
- without a source of food (i.e. energy), the plants would die.

In response to the " villain " question, five main categories of response were identified by Bell.

1. Responses including only components of the accepted answer.
2. Responses including alternative consequences and/or explanations.
3. Responses including alternative ideas on plant nutrition.
4. Responses including scientifically unacceptable ideas about the function of chlorophyll.
5. Other responses.

Transkei pupils' responses were analysed in the light of the above categories and fell into four categories, that is, 1,2,4 and 5.

Table 4.7 gives a comparison of Bell's findings and the researchers' finding.

TABLE 4.7

RESULTS FOR THE VILLAIN QUESTION FOR BELL AND TRANSKEI PUPILS

CATEGORY OF RESPONSE	BELL'S PUPILS n = 308	TRANSKEI PUPILS n = 308
Responses including only components of the accepted answer.	38	64
Alternative consequences and/or explanations	21	20
Alternative ideas on plant nutrition	3	—
Scientifically unacceptable ideas about the function of chlorophyll	19	6
Other responses	19	10
	100	100

1 Responses including only components of the accepted answer.

An accepted answer according to Bell, requires an account of the consequences of destroying the chlorophyll and an explanation.

About 64% of all responses could be classified in this category. The following are some of the responses:

- a) Responses involving chlorophyll, photosynthesis and death.

About 19% of the responses were placed in this category. The following are some of the responses:

- This will damage the plant life, for chlorophyll is that green pigment in plants which is used during the process of photosynthesis. If there will be no chlorophyll there will be no photosynthesis and the plant will not be able to make its own food and it will eventually die.

chlorophyll helps to absorb the radiant energy from the sun. This energy is used in the process of photosynthesis. Once this chlorophyll is destroyed, plants will not be able to manufacture the food and they will die due to lack of food.

- b) Responses including death and inability to manufacture food (No mention of chlorophyll).

About 12% of the responses contained ideas about death and photosynthesis. The following are examples:-

- the plants will die because no photosynthesis takes place in that plant.

the plants will be unable to manufacture their food, that is, photosynthesis will not take place resulting in the death of the plant.

- c) Responses including only the resulting death of plants.

About 5% of the responses included the resulting death of plants, for example,

- the plants will die.
- the plants in the whole countryside will die.

d) **Responses including death and chlorophyll**

About 2% of the responses contained ideas about death and chlorophyll:

- the plant will die immediately the chlorophyll is not there.

e) **Responses including chlorophyll and photosynthesis.**

About 22% of responses contained ideas about chlorophyll and photosynthesis as in the following examples:-

- if the plant has no chlorophyll it means that the plant cannot manufacture its own food during photosynthesis.
- Once the plant lacks chlorophyll it means that it cannot be able to manufacture food even if the light and other useful substances are present.

f) **Responses including colour change.**

About 4% of the responses mentioned the colour change only:

- Once the plant lacks chlorophyll, it is going to lose the green colour and become yellow.

2. Responses including alternative consequences and/ or explanations.

About 20% of the responses were classified in this category.

Responses included the following:

a) **lack of oxygen**

Some responses (8%) included death due to lack of oxygen as in the following examples:-

- there will be death because there will be lack of oxygen. The plants are the source of oxygen.

- the plants will not survive because of shortage of oxygen, animals too will not survive.

b) death of heterotrophs

Some responses included the death of heterotrophs (5%) for example,

- that would lead to chlorophyll deficiency and the animals which depend on plants for food will die.

c) Other ideas (Ideas which are scientifically correct but not relevant to the question).

About 4% of responses contained ideas about referred to as "other ideas". for example,

- the plants will be of a yellowish colour which clearly indicates unhealthy plants. The auxins responsible for the production of chlorophyll will not function properly.
- the plant life will be destroyed by the chemical. These destroyed plants could be useful as the soil cover preventing soil erosion.
- the plants'leaves all die. There will be no more green plants again. But the dead may be acted upon by decomposers in the soil.

d) growth

Some responses included growth (3%) as in the following examples:

- without chlorophyll the plant will not grow.
- no chlorophyll, no food, no growth.

3. Responses including unacceptable functions of the chlorophyll.

About 6% of the responses fell in this category of responses as in the following examples:-

- the green substance in plants makes food to keep the plant alive. If the plant is not green it means that there are no substances that can feed it.
- the plant will die because energy which is necessary for metabolic processes is obtained from chlorophyll.

4. Other Responses.

About 10% of responses were categorised as other responses which included no responses and unclassified responses.

QUESTION 3. "GROW - TREE"

An accepted scientific response would , according to Bell, contain the following ideas:

- plants take in water (and minerals) from the soil, through the roots, and carbon dioxide from the air mainly through the leaves.
- using the water and carbon dioxide, in the presence of chlorophyll, the plant converts light energy to chemical energy and manufactures food substances, such as glucose.
- some of the energy - containing substances (food) are used for making new plant cell, which

Driver, et al (1984) analysed the responses of 15 year old pupils' extended written responses to the "APU" "grow - tree" question. The question was designed " to be open - ended in

order to assess whether pupils spontaneously use the idea that plants make their own tissue from basic constituents, carbon dioxide and water, taken in from the environment." From the pupils' responses, four main types of response were identified, namely,

- Tree grows because it makes tissue from constituents it takes from its environment.
- Tree grows because of what it takes in from its environment.
- Tree grows because it takes in food from its environment- from soil
- from sunlight
- Tautology - tree grows because it gets bigger ...
- No response, uncodeable, don't know.

Bell used the same response categories in analysing oral responses of 25 pupils in an interview situation.

An analysis of Transkei pupils' responses showed a greater diversity and it was not possible to use only the categories suggested by Driver et al (1984) and Bell (1986). The following are the categories used:-

- Tree grows because of what it takes in from its environment

Pupils' ideas focussed mainly on the constituents of photosynthesis. 39% of responses were placed in this category. Responses included the following:-

a) **Water only**

- there is water which the tree finds, so it make the tree grow.
- the plant has gained the mass from the water absorbed from the soil.

b) **Water and mineral salts**

- the plant has absorbed much water from the soil and some mineral salts which will fill the cytoplasm of this plant causing the weight to increase

c) **Soil**

- It is coming from the soil.

d) **Soil Nutrients**

- It comes from the soil nutrients on which the plants feed so that it can have normal growth.

e) **Soil and Sunlight**

- from fertile soil and sunlight.

f) **Water, air and sunlight**

- the plant will grow since it is exposed to sunlight, water and air which are necessary for plant growth.

g) **Water and sun**

- the roots absorbs water from the soil. There is also sunlight which is absorbed by the chlorophyll. These cause the tree to grow.

h) **Water and nutrients**

- the tree has roots which have root hairs to collect water and nutrients for the tree.
- The tree became big and heavy because it has everything.

i) **Radiant energy, air, mineral substances**

- Radiant energy from the sun has brought about the tree to grow. The air from the atmosphere and mineral substances from the soil have brought about the growing of the tree up to this point.

j) **Carbon dioxide, water and mineral salts**

- from carbon dioxide in the atmosphere, water and mineral salts from the soil.

k) **Water, mineral salts and sun.**

- It comes from the environment in which it is, the water, mineral salts from the soil & sun.

l) **Sunlight, water, carbon dioxide and nutrients**

- It is because there will be sufficient factor. It is having the sunlight, water and carbon dioxide and also some nutrients.

m) **Mineral salts, carbon dioxide and sunlight**

- it comes from mineral salts, carbon dioxide and sunlight.

n) **Oxygen**

Oxygen is mentioned as one of the requirements of photosynthesis, for example,

- it weighs 250kg because the tree had been getting water, sunlight, oxygen, minerals etc., which are the ones that cause photosynthesis in plants and photosynthesis causes growth.

2. Growth and Development.

34% of all responses were placed in this category. Some pupils' ideas focussed mainly on the mechanisms of growth. No attempts were made to show the link between food and tissue formation. The following are some of

the responses:-

a) **Cell division**

About 15% of the pupils attributed the growth of the tree to cell division. The following are some of the responses:-

- Cell division and cell elongation have brought about the extra 250kg.
- It comes from the plant itself. Over the years its cells were continually dividing.

b) **Growth Hormones**

About 4% of the pupils attributed the growth of the tree to the action of growth hormones as in the following examples :-

- due to the presence of growth hormone Indole Acetic Acid needed for growth, the mass of the tree increased tremendously.
- The plant has to grow by its nature with the help of getting food and hormones found in it.

c) **Growth Movements**

About 3% of the pupils attributed the growth of the tree to growth movements in response to external stimuli, for example,

- The small tree contains auxins. When the plant is exposed to light, the stem grows towards the light stimulus.

d) **Development of tissues**

About 4% of the responses contained ideas about tissue development, although no attempts were made to link it with other life processes, for example,

- When the tree or every organism is growing, it gains more and more weight because of the development of the tissues.

e) **Maturity**

A very small proportion, about 1% of the pupils tested mentioned maturity as in the following example;-

- the tree now is fully mature, it has leaves, and strong stem. It has been fully supplied by food and nutrients.

f) **Secondary Thickening**

About 3% of the responses mentioned secondary thickening. Some pupils mentioned secondary thickening only as in the following example:-

- the growth of the tree is due to secondary thickening of the cells.

Some responses in addition to secondary thickening, mentioned other processes, although no links are shown, for example,

- the small plant through undergoing cell division, photosynthesis and respiration will be able to grow and secondary thickening will cause the plant to increase in size.

3. Tree grows because of food

13% of the total responses were placed in this category of responses.

About 5% of the responses in this category attributed the growth of the tree to the food it manufactures, for example,

- from the food which the tree synthesises in order to live.

About 4% of the responses considered the growth of the tree to be due to food it makes and cell division. However, no attempts were made to link the two. It would appear that the syllabus structure affected the way pupils responded. Cell division is taught in Std 9 and photosynthesis in Std 10. All the metabolic processes occurring prior to cell division are lost sight of. The following are some of the responses :-

- the small plant through undergoing photosynthesis and cell division was able to grow and increase in size.
- A plant prepares its own food with the help of the energy from the sun. Some of the food is stored by plants and some is used during cell division. Cell division makes the plant big.

4% of the responses in this category attributed the growth of the tree to constituents the tree gets from the environment and the food it makes. The following are some of the responses:-

- from CO₂ in the atmosphere, water and mineral salts from the soil which are transported to the leaves where photosynthesis takes place.
- it has obtained energy from the sun and necessary raw materials from the soil and manufactured its own food.

4. Tree grows because of food it takes in from the environment

About 3% of the responses were placed in this category of responses. Heterotrophic nutrition is implied as in the following examples:-

- the tree grows upright because there is enough food, water and sunlight. Therefore the tree gets its food and water from the soil.
- the tree got extra 250kg from the soil. The roots have provided it with food, water and mineral salts which makes growth to be normal.

5. Tautology

About 5% of the responses were placed in this category of responses. The following are some of the responses:-

- extra 250kg come from leaves, stem, branches and roots that became bigger and bigger.
- the tree has grown bigger and bigger so its size is not the same as it was that's why it is weighing more than when it was planted.

6. Energy

About 2% of responses contained ideas about energy as in the following examples:

- Radiant energy causes the tree to grow.
- Availability of energy that comes from glycolysis.
- Availability of energy in the tree.

7. Other Responses

About 4% of the responses fell in the category of other responses.

CHAPTER 5

5. DATA PRESENTATION AND ANALYSIS

5.1. INTRODUCTION

In this chapter data obtained through the use of the photosynthesis concept test and concept maps will be presented and analysed.

CONCEPT TEST 2 PHOTOSYNTHESIS CONCEPT TEST

The photosynthesis concept test comprised the following tasks:-

Problem 1

Problem one involved two tasks. It involved a short story or description aided by diagrams (Appendix 111). Task No 1 required pupils to choose the correct answer from three statements provided. The question was designed to probe the role pupils ascribe to soil in the process of photosynthesis. The question read as follows:-

"What do you think must have happened to the weight of the soil in the tub after the plant grew in it for five years and gained much weight?"

Responses to the question are shown in Table 5.1

TABLE 5.1

RESPONSES TO PROBLEM 1. TASK NO 1

RESPONSE OPTIONS	WANDERSEE'S 11 TH GRADES	TRANSKEI PUPILS n = 242
1. The soil lost a lot of weight	31,9%	54,5%
2. The soil's weight stayed about the same	65,0%	23,6%
3. The soil gained a lot of weight	3,1%	21,9%
	100%	100%

Wandersee considered 2 to be the correct answer - the soil's weight stayed about the same. 54,5% chose 1 - the soil lost a lot of weight. The majority of the pupils who chose this response option attributed the loss of weight by the soil to absorption of water and mineral salts.

The idea of nutrient recycling seem to be overlooked or does not exist in the minds of the pupils or they do not relate that with the question. The fact that plants manufacture their own food using the raw materials from the soil and CO₂ from the atmosphere seem to have been forgotten. According to them plants obtain their "food" from the soil and that is why the soil lost a lot of weight.

The following are some of the responses given:

- It lost a lot of weight because its mineral has been used by the plant and much of its part has been used by the plant for its growth.
- Since plants have obtained a lot of mineral salts and water from it. these are part of the weight of the soil. There will be less water and mineral salts.

Problem II

This problem involved three tasks, that is, Tasks 3, 4 and 5. The test was designed to study the perceptions students have of the relationship between photosynthesis and animal respiration in the carbon cycle. The problem involved a mouse placed in a closed container with food. The food was later replaced by a plant which was placed on a shelf where the mouse could not reach.

Task three, required a single response to four statements.

Responses to the task are given in Table 5.2.

TABLE 5.2

RESPONSES TO PROBLEM II TASK NO. 3

RESPONSE OPTIONS/STATEMENTS	TRANSKEI PUPILS
1. The plant would die but the mouse would live	2,1%
2. The mouse would die but the plant would live	30,2%
3. Both the mouse and the plant would live	45,0%
4. Both the mouse and the plant would die	22,7%
	100%

The researcher had problems in choosing the correct answer in this problem. The information provided is not sufficient and consequently there are many possibilities. 30,2% of the pupils who answered the PCT chose 2 as the correct answer. 2 is possibly an acceptable response if a valid reason is given. There is no way that the pupils would know if the plant was producing sufficient oxygen for the mouse to survive. Mice have fairly high metabolic rates.

The dominant misconception regarding option 2 is that the pupils placed more importance on food for survival than on oxygen. About 20% of the responses contained such ideas as in the following examples:

- the mouse would die because it could not reach the plant for food and the plant remains growing getting the light from the sun.
- the mouse would die of hunger.

A small percentage (4%) responded thus:

- the mouse would die because of lack of air, the plant would live.

Some responses (6%) involved lack of oxygen.

- the mouse does not get oxygen while the plant gets sunlight.
- the plant gets sunlight and the mouse does not get oxygen and so it dies.
- plants breathe in CO_2 and animals breathe in oxygen so there will be too much CO_2 and no oxygen for the mouse to breathe in.

From the first two responses regarding lack of oxygen, there is no mention of photosynthesis and respiration as complementary processes. Lack of oxygen is attributed to the closed container in which the plant and mouse are placed. "The plant lives because it receives the sunlight". Nothing is said about the role of sunlight in photosynthesis. Coming to the third example, there is the misconception that plants breathe in CO_2 while animals breathe in oxygen. Pupils do not seem to understand that both processes, that is, photosynthesis and respiration occur in autotrophic plants. Photosynthesis is associated with plants and respiration is associated with animals. They forget that plants and animals are living organisms and all living organisms respire.

45% of the pupils tested chose option 3, that is, both the mouse and the plant would live. The question does not specify the duration of time the plant and the mouse were kept in the closed glass container. The pupils could argue that during photosynthesis carbon dioxide is taken in by the plant and oxygen is released. On the other hand both the plant and the rat breathe in oxygen. So as long as there is enough oxygen, the two would live.

The following are some of the responses to this question:

- it is because during photosynthesis the plant will take in CO_2 and give out O_2 and the mouse will take in O_2 and give out CO_2 and there will be a negative feedback in order to keep life going on.

Option 4 - both the mouse and the plant would die was chosen by 22,7% of the pupils tested. The following is an example of some reasons provided for choosing this response option.

- They would die because in this container there is no oxygen, its filled with carbon dioxide. Even that plant has no light and chlorophyll so it must die, no water in the container.

TASK 5

This question asked the pupils which gas might decrease in amount after the mouse had been living in the closed glass container (without the plant). The task's aim was to determine whether pupils could identify the gas needed for respiration. The response options included water, oxygen, carbon dioxide and nitrogen, that is, the major gaseous components of air. The responses to the question are given in Table 5.3.

TABLE 5.3

RESPONSES TO TASK 5 (PROBLEM II)

RESPONSE OPTIONS	WANDERSEE'S	TRANSKEI PUPILS
	11TH GRADES	n = 242
1. Water	12%	5,8%
2. Oxygen	75%	76,4%
3. Carbon Dioxide	6%	13,2%
4. Nitrogen	7%	2,1%
No response	-	2,5%
Total	100%	100,0%

76,4% of the pupils tested chose the correct answer, that is, oxygen 13,2% chose carbon dioxide. There is still confusion of the role oxygen and carbon dioxide in explaining respiration.

Problem III

The problem involved two tasks, that is, six and seven. Six required the main function of a leaf and involved a single response to four statements.

Responses to the question are provided in Table 5.4

TABLE 5.4

RESPONSES TO TASK 6 (PROBLEM III)

RESPONSE OPTIONS	WANDERSEE'S	TRANSKEI PUPILS
	11TH GRADES	n = 242
1. Leaves serve to shade the tender young shoots of the plant from the hot sun	4%	2,5%
2. Leaves catch rain and dew plants need to live	12%	5,4%
3. Leaves make food...	73%	83,4%
4. Leaves capture the warmth of the sun	11%	8,3%
No response	-	0,4%
	100%	100,0%

The accepted answer is three - leaves make food that keeps the plant alive. 83,4% of the pupils tested knew the main function of a leaf.

Task seven involved three subtasks, concerned with the movement of gases into and out of the leaf during photosynthesis. Subtask A sought to know whether the pupils knew the primary flow of carbon dioxide gas was into or out of the leaf during photosynthesis. 81% of the pupils tested chose the accepted answer - carbon dioxide moves into the leaf and 18,2% chose oxygen as moving into the leaf.

Subtask B was concerned with the movement of water vapour during photosynthesis. It sought to learn whether the pupils knew the direction of flow of water vapour during photosynthesis. 61.5% of the pupils tested chose the accepted answer - water vapour moves out of the leaf.

Subtask C required pupils to indicate the direction of flow of oxygen during photosynthesis. 75.6% of the pupils tested chose the accepted answer - oxygen moves out of the leaf.

TABLE 5.5
RESPONSES TO TASK 7. SUBTASKS A,B and C.

GAS	DIRECTION OF FLOW			
	INTO THE LEAF		OUT OF THE LEAF	
	WANDERSEE	TRANSKEI	WANDERSEE	TRANSKEI
Carbon Dioxide	84%	8%	16%	18,2%
Water Vapour	68%	6,2%	32%	61,5%
Oxygen	17%	- %	83%	75,6%

Problem IV

The problem sought to know whether the pupils knew the primary source of food in plants. Task eight called for a single response from four response options. The results are provided in Table 5.6.

TABLE 5.6
RESPONSES TO TASK 8 (PROBLEM IV)

RESPONSE OPTIONS	WANDERSEE'S 11TH GRADES	TRANSKEI PUPILS n = 242
1. The food of plants comes from water	7%	3,7%
2. The food of plants comes from carbon dioxide	2%	14,0%
3. The food of plants comes from soil	68%	66,5
4. The food of plants comes from water and air	23%	14,9
No response	-	0,82%
Total	100%	100%

The accepted answer, according to Wandersee, is 2, that is, the food of plants comes from carbon dioxide. The researcher had problems with this question. The wording of the problem is rather dubious. One could therefore infer that the pupils also had problems in answering the question. Some teachers who answered the test also expressed the same feeling about the question.

The food of plants is considered to come from carbon dioxide. It would be better to say carbon dioxide is the source of

carbon during photosynthesis.

66,5% of the pupils tested chose option 3 - the food of plants comes from the soil. Although this response option is not correct, because of the wording of the question, the pupils might have been tempted to choose it as the correct answer

Societal practices as was indicated by Wandersee in chapter 3 have had a major influence in cultivating this cultural misconception in our pupils and teachers as well.

Task nine required explanation of the response options in task eight.

The following are some of the reasons given by pupils for choosing the response option

- the food of plants comes from water.
- plants need water to grow. It cannot grow from the soil without water.
- it can be planted in the soil and the result will be no growth and water is necessary to promote growth of the plant.

Reasons for the second response option, that is, the food of plants comes from carbon dioxide are given.

- the plant needs carbon dioxide to manufacture food.
- the plant leaf combines CO₂ and water to manufacture food.

Reasons for option three, that is, the food of plants comes from the soil are given below:-

- the plant absorbs its food from the soil
- the plant gets food from the soil because in the soil there are minerals and also water.

In the examples above the pupils confused raw materials like water and mineral salts with organic food. Some pupils however, recognised the fact that root hairs absorb water and mineral salts from the soil and the plant manufactures its own food as in the following examples: -

- in the soil, it is where there are mineral salts, dissolved ions and water which are absorbed by roots to leaves where food is manufactured and then transported to other parts of the plant by phloem vessels
- a plant has root hairs deep down in the soil. These root hairs absorb mineral salts found in the soil and also water. These substances are then sent to the leaves where the plant can make its own food

Reasons for the fourth option, that is, the food of plants comes from water and air will now be considered.

- roots of plants absorb water from the soil and air from the atmosphere enters through the stomata of the leaves.
- the plant cannot grow without water and air.
- water combines with carbon dioxide to form carbohydrates.

PROBLEM V

The task was designed to test the pupils' perception of the effect of sunlight on plant growth. Task ten involved two potplants of the same kind and size being put in different places. One was put on a closed shelf and one was placed on a windowsill for about a month. Both plants had been kept watered. The task requested students to draw the plants to show their appearance after one month.

Pupil responses to the question involved correct diagrams, incorrect or similar diagrams and those who did not respond. About 65% of the pupils drew correct diagrams - the plant that was placed on the window sill appeared strong and healthy; others showed the plant bending towards light. The closet plant appeared sickly and thin. About 20% of the pupils either drew similar diagrams - there was no difference between the closet plant and the plant exposed to sunlight or else the closet plant would appear bigger and healthier than the one placed on the window sill. About 15% involved either no response or diagrams which could not be categorised.

PROBLEM VI

The problem was concerned with the main product of photosynthesis. Task II required a single response from three response options, namely, proteins, fats and carbohydrates. Responses to the question are provided in Table 5.7

TABLE 5.7
RESPONSE TO TASK II (PROBLEM VI)

RESPONSE OPTIONS	WANDERSEE'S 11TH GRADES	TRANSKEI PUPILS n = 242
1. Proteins	58%	12,8%
2. Fats	1%	4,1%
3. Carbohydrates	41%	81,4%
No response	-	1,7%
Total	100%	100%

The accepted answer - carbohydrates, was chosen by 81,4% of the pupils tested. Proteins did not appear to be a dominant misconception as only 12,8% of the pupils tested chose proteins. According to Wandersee 46% to 59% of the pupils selected across all three grade levels selected proteins as the correct answer. The accepted answer was chosen by 37% to 41% of the grade levels under study. Only the Collegian sample contained more respondents choosing carbohydrates (51%) than proteins (46%). Very few respondents chose fats.

Problems VIII

This problem involved task twelve which was intended "to probe the students' awareness and understanding of the pigment chlorophyll and its role in photosynthesis." Pupils

were asked to explain how the colour change of deciduous tree leaves in autumn affects the leaf's main function. The word "autumn" does not appear in the original text, "fall" was used instead. The researcher decided to use autumn since Transkei pupils are more familiar with the term autumn than fall. The expected response was that "the leaf can no longer absorb sunlight for photosynthesis because its chlorophyll (in its chloroplast) is no longer intact and functional."

To analyse the pupils' responses some of Bell's categories of responses in the "hay-today" question were used.

1. Responses including only components of the accepted answer

About 62 percent of responses were placed in this category.

Responses included the following:

(a) Responses involving photosynthesis, chlorophyll and sunlight

About 15% of the responses contained the such ideas of which 13% could be considered correct, for example,

The leaf can no longer

- manufacture its own food because it has lost chlorophyll and the leaf can't trap radiant energy from the sun.
- manufacture food because the green pigment, that is chlorophyll which absorb radiant energy is not working. No light energy will be absorbed and therefore that affects the leaf's main function.

Some responses (2%) were partially correct. These responses showed confusion of the role of CO_2 and O_2 in photosynthesis. Some pupils recognised that oxygen is involved but not clear whether as a requirement or a by-product of photosynthesis. Some examples are given:

The leaf can no longer

- produce its own food by means of photosynthesis because it does not possess chlorophyll. In order for plant to manufacture its own food chlorophyll must be there. The production of plant food takes place in the chloroplast in the presence of sunlight, oxygen and water.
- there is no chlorophyll, but O_2 , CO_2 and sunlight is present. Photosynthesis cannot take place if one of the four aspects is not available.

(b) Responses including photosynthesis and chlorophyll only

About 24% of the responses included photosynthesis and chlorophyll only. The pupils knew that chlorophyll is one of the essentials for photosynthesis, but its exact function, that is, absorbing light energy or radiant energy is not mentioned. The following are some of the responses: The leaf can no longer

- manufacture its food during photosynthesis because it has lost its chlorophyll.
- produce carbohydrates or undergo photosynthesis because it does not have the green pigmentation any more, that is, chlorophyll.

(c) Responses including photosynthesis and the green colour/pigment (No mention of chlorophyll)

About 11% of the total responses were placed in this sub-

category. Here there is no mention of chlorophyll at all.

The following are some of the responses:

The leaf can no longer

- manufacture its own food because it has no green colour in it.
- undergo photosynthesis because this process occurs in the presence of the green colour.

(d) Responses including photosynthesis only

(no reasons given)

About 3% of the total responses mentioned photosynthesis only. The following are some of the responses given:

The leaf can no longer

- manufacture food
- manufacture food or undergo the process of photosynthesis.

(e) Responses including green colour and chlorophyll

About 1% of the total number of pupils tested mentioned or attributed the colour change to loss of chlorophyll as in the following examples:

The leaf can no longer

- be green in colour because the chlorophyll is lost
- be green in colour due to lack of chlorophyll.

(f) Responses including chlorophyll, photosynthesis and death

About 2% contained the ideas mentioned above, for example,

The leaf can no longer

- manufacture its own food so it will no longer live instead it will die because by losing green colour

that shows that there is no more chlorophyll to help it in making food.

- be able to manufacture its own food and its possible that it can die because it has lost its chlorophyll.

(g) Responses including dryness of the leaf

About 4% of responses contained such ideas :

The leaf can no longer

- produce food that kept the plant alive because leaves change the colour and become dry.
- produce food because when they change their colour they become dry.

(h) Change of Season (Nothing is said about what brings about the colour change)

About 2% of the responses were placed in this category.

The leaf can no longer

- contain a green colour because of the changing of the season.
- become green in colour throughout the year because of the seasons. In winter the leaves become dry and fall.

2. Responses including alternative ideas for the colour difference

About 26% of the total responses were placed in this category of responses. A number of ideas were encountered.

(a) water

About 16% of the responses contained ideas about shortage of water, or lack of rain. The following are some of the responses:

The leaf can no longer

- get enough rainfall to support the leaf, because there is scarcity of rainfall at this season (Water seem to have a supporting function)
- live without water, because it absorbs water and make food for a plant
- manufacture its food without water from the roots because in late Summer there is less rain to give water for photosynthesis.
- the leaf can no longer live without water because water makes the leaf to grow and water is the food for the plant, because it has some mineral salts to support the plants.

In the second example, water is seen as a constituent of photosynthesis, so if one of the constituents of photosynthesis is missing, the leaf will not be able to manufacture food for the plant.

In the fourth example, water is seen as the "food" for the plant.

(b) Water and sunlight

About 10% of the responses contained ideas about water and sunlight.

Some pupils (3%) attributed the loss of the green colour to lack of water and too much sunlight as in the following examples:

The leaf can no longer

- have chlorophyll or water present in the leaf because it was exposed to the sunlight for a long time in summer.
- The plant has received a lot of sunlight, so now

it will change its colour because of summer that has passed and received a lot of sunlight.

The following contained ideas about lack of water and sunlight (7%).

- The green in late summer and early autumn because sun is not so bright for making green chlorophyll.
- remain green in colour, the sun is not enough for the process of photosynthesis and all the plant nutrients have been taken by the fruit produced.
- stay green because the leaves need the strong rays of the sun to be green. Green pigment depends on light.

3. Responses including scientifically unacceptable function of the chlorophyll

A very small proportion (7%) of the responses contained a lack of understanding of function of chlorophyll. Some responses contained ideas about heterotrophic nutrition as in the following examples.

The leaf can no longer.....

- produce food for us and it is also no longer green in colour because it does not gain water in that season and the sun will be no more strong.
- become suitable for animals which eat leaves because it does not contain chlorophyll which is the green pigment in a plant.

Some responses included growth, for example,

The leaf can no longer...

- grow up, it will die because the loss of the green chemical affect the leaf because food comes from green part of a flower (leaf is mistaken for a flower).
- live because when the green colour is lost the chlorophyll will not take food to the stem, and the plant will die.

Some responses contained ideas about chlorophyll being responsible for the manufacture of food, for example, The leaf can no longer...

- be green and chlorophyll will no longer make food for the plant.
- have chlorophyll to supply the stem with food. When the tree becomes dry the leaves drop down.

4. Other Responses

In this category were placed no responses and unclassified responses. About 5% of the total responses were placed in this category of responses.

4.4 CONCEPT MAPS

Concept mapping was administered to 63 pupils doing Std 10 as stated in chapter 3. Because of the time factor no attempt was made to assess pupils attitudes towards concept mapping. My observation was that some pupils did not seem to like the strategy because other teachers in the school were not using it. Some pupils still had problems with proceeding from the most general term towards the most specific. Since these pupils were in Std 10 at the time there was no follow up to see whether they implement the strategy in learning.

Concept mapping, as mentioned in chapter 3, was also introduced to Biology teachers who attended the Std 8, 9 & 10 courses in 1988 and 1989. Even here, some teachers showed reluctance, but others appeared to enjoy the strategy.

Sample concept maps drawn by pupils are labelled Figure 1, 2 and 3. No concepts were provided, pupils were required to draw concept maps to show their understanding of photosynthesis.

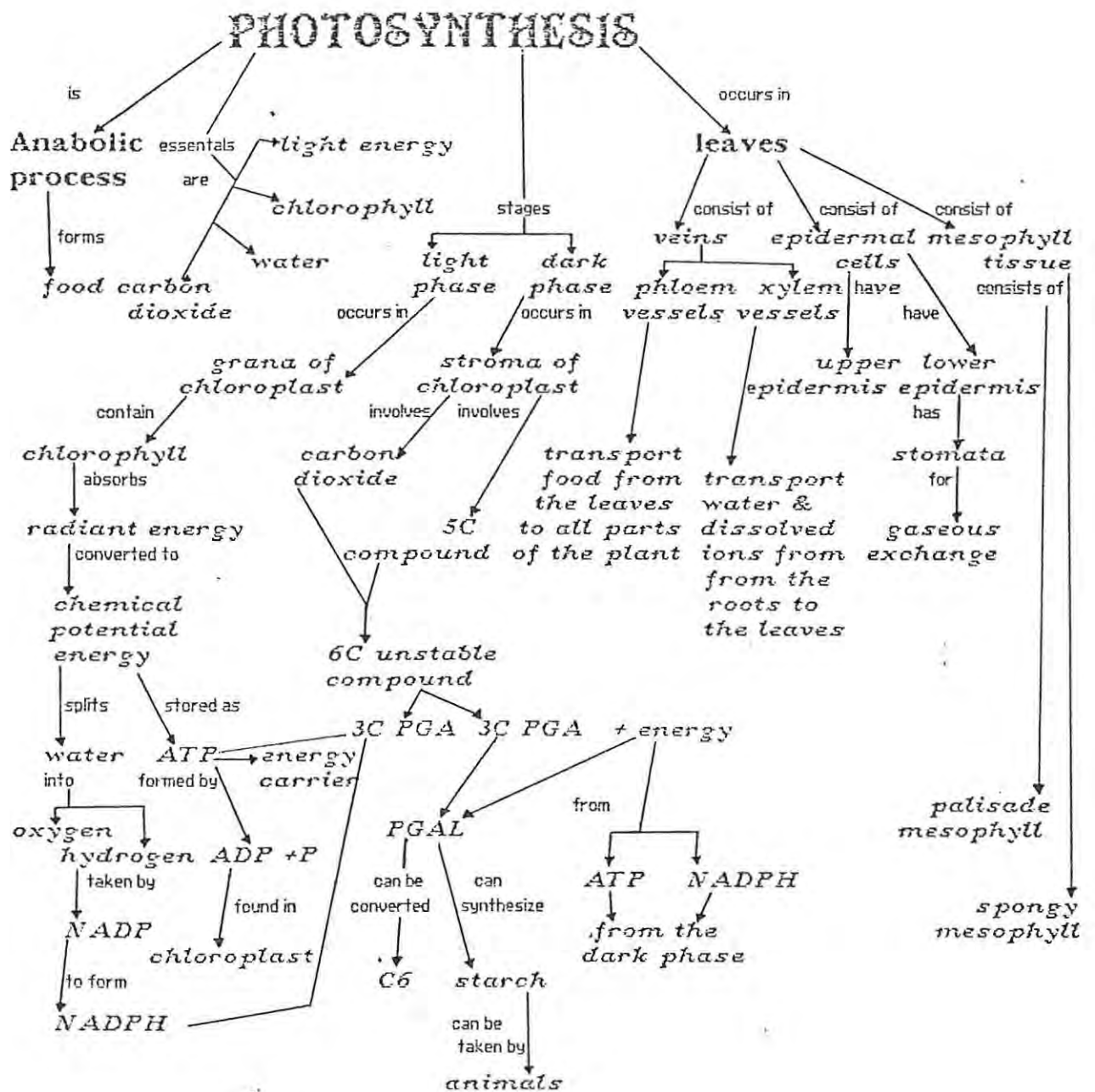


FIGURE 2

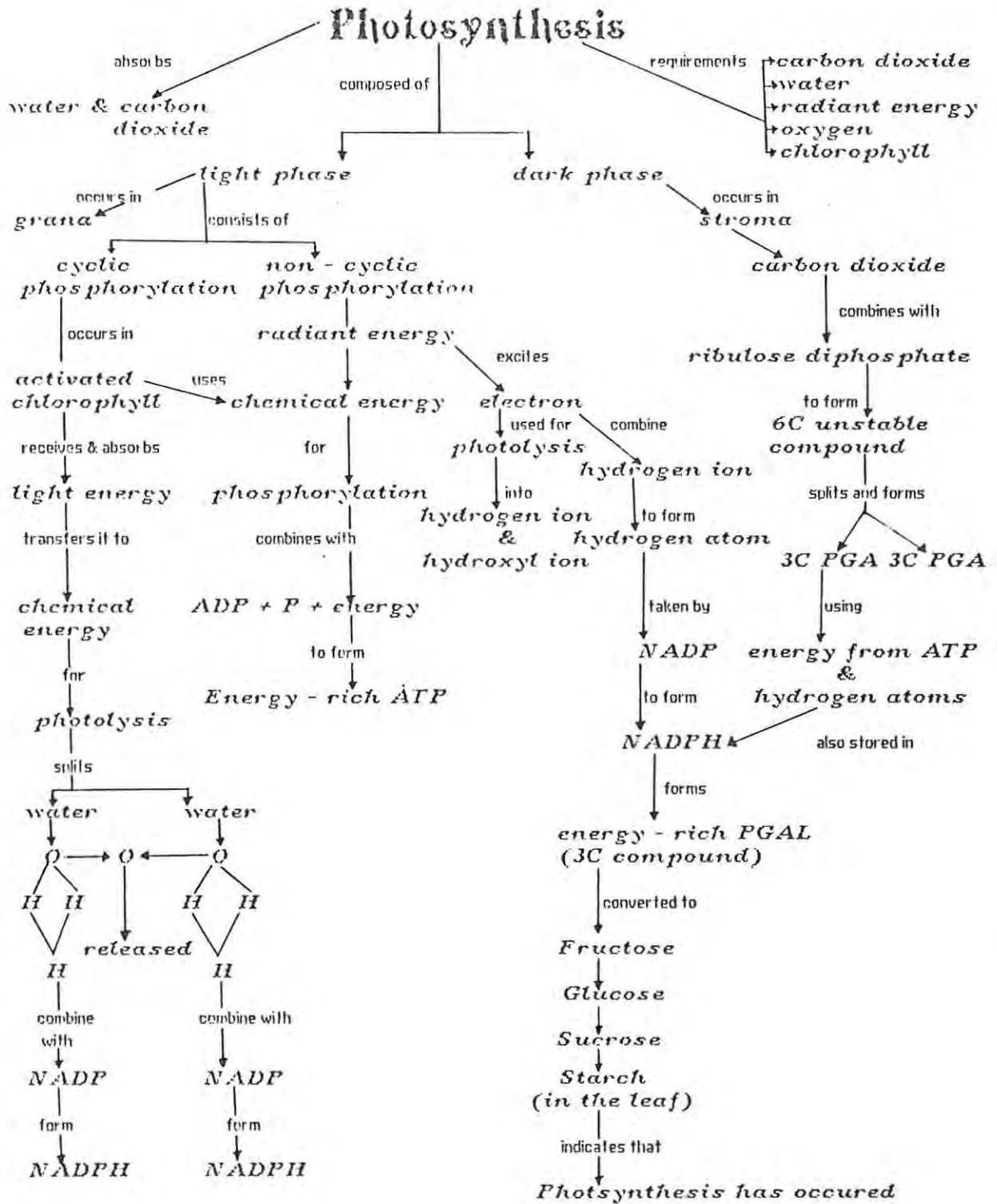


FIGURE 3

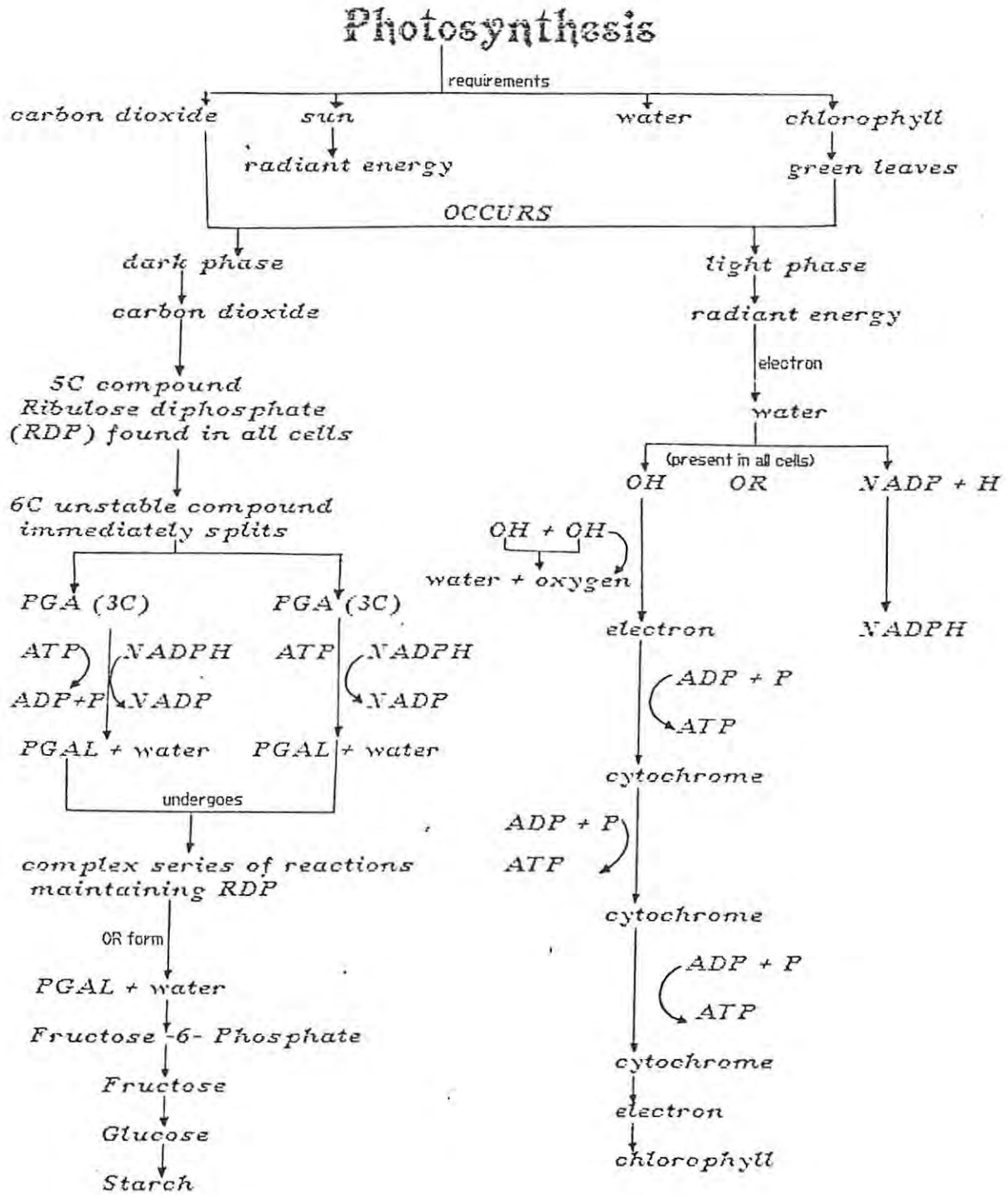


Figure 1 shows a better understanding of photosynthesis than figures 2 and 3. Photosynthesis is recognised to be an anabolic process. Steps of the light and dark phases are traced. Some products of photosynthesis are shown to be consumed by animals. Essentials of photosynthesis are shown. The leaf is identified as the organ where photosynthesis occurs and its role in transporting the photosynthetic end products is shown. The link between the two phases is shown. The roles of the chloroplast and chlorophyll in photosynthesis are shown.

There are however, shortcomings which are detected. Photosynthesis is confined to the leaves. The Std 9 work appeared to have been forgotten. Some herbaceous stems, mosses, ferns, and bacteria, for example, contain chlorophyll and therefore carry on photosynthesis.

The fate of the photosynthetic end - products in the plant is not shown. The metabolic link between photosynthetic end - products and other processes, for example, protein and enzyme synthesis, nucleic acid synthesis, lipid synthesis and synthesis of other organic compounds is not indicated.

The relationship between photosynthesis and respiration is not shown. The end - products of photosynthesis, that is, nutrients and ATP, are necessary for the cell to carry out other activities including respiration. PGAL formed during photosynthesis can serve as prime respiratory fuel.

In figure 2, oxygen is mentioned as one of the products of photosynthesis. The link between the two phases of photosynthesis is shown. Some linking words need to be improved, for example, "light energy transfers it to chemical energy". It is difficult to make out what the pupil had in mind. Some linking words are missing. Even with the first concept maps some linking words are missing.

It was difficult to analyse the third concept map. There are some blocks the intention of which is not known. Linking words are missing.

Concept maps drawn by teachers are found in Appendix V. They have been included to stimulate further research on concept mapping as means for testing one's understanding of concepts.

CHAPTER 6

6 DISCUSSION OF RESULTS

6.1 INTRODUCTION

This chapter will focus on the discussion of the results of this study and will make possible suggestions and recommendations. Questionnaires, interviews, both structured and unstructured, concept tests and concept maps were tools used to collect data in this study.

6.2 QUESTIONNAIRES AND INTERVIEWS

The results of the questionnaires indicated a lack of chemistry background by some pupils. 31,8% of the pupils tested did not do physical science in Std 8, and 42,8% of those who did it in Std 8 obtained a symbol lower than a D. The interviews also indicated a lack of chemistry background by both teachers and pupils.

Some Biochemistry topics are perceived as difficult by teachers and pupils. However, some topics considered difficult by teachers are considered easy by some pupils, for example, photosynthesis. Research by Johnstone and Mahmoud (1980), Simpson and Arnold (1982), Wandersee (1983), Bell and Brook (1984), for example, has indicated that photosynthesis is not fully understood by pupils. Examiner's reports and interviews have also indicated that photosynthesis is a problem both to teachers and pupils.

The pupils investigated appeared to be familiar with the concept of photosynthesis rather than understanding it. In the Std 7, 8 and 9 syllabi very little is said about the process of photosynthesis except that pupils are exposed repeatedly to the idea of green plants serving as producers in an ecosystem. Some teachers may attempt in broad outline to explain the meaning of the term producer in terms of the roles of chlorophyll, light, water and carbon dioxide in a food producing process called photosynthesis. The study of the cell in Std 8, sheds more light on the nature, location and role of chlorophyll in a plant and this consolidates further the knowledge gained earlier about a producer.

Simpson and Arnold (1982) remarked that the classification of green plants as producers and animals as consumers is misleading as it gives the impression that plants do not manufacture food for themselves, but for animals referred to as consumers. The plants also consume the food they manufacture. This classification reinforces the misconception that plants obtain their food from the environment, either from soil, water or air and should therefore be treated with care.

Pupils' knowledge of photosynthesis before Std 10 is limited to a process through which producers manufacture food. When the time for teaching the actual process of photosynthesis comes in Std 10, the teacher is aware that he has a mammoth

task of introducing and teaching a process with far - reaching biochemical implications to pupils who are satisfied with scanty knowledge gained earlier and some of whom do not have a good enough background knowledge of basic chemistry.

The problem is compounded further for the teacher by a condition in the syllabus which states " Study of the biochemical mechanisms not required." Any teaching strategy that does not go far enough in explaining the biochemical mechanisms makes it exceedingly difficult to give a comprehensive account of what is taking place in photosynthesis. The teachers' dilemma becomes worse when some of the questions asked by examiners require a working knowledge of the biochemical mechanisms. There is therefore confusion on the part of the teacher as to what to teach.

The reasons given by pupils for difficult biochemical topics, and the results of the interviews appeared similar. Both pupils and teachers complained about lack of chemistry background, lack of laboratory equipment and practical work not being done. These, it would appear, have cultivated a negative attitude on both pupils and teachers towards the subject.

Since it has been shown that some teachers are underqualified, and the conditions of some schools are not conducive to learning as there is a drastic shortage of

seating accommodation and equipment, some suggestions by teachers and other persons interviewed appeared valid. The results pointed to a need for suitably qualified teachers. They saw a need for in - service training of teachers as they need to be upgraded in the subject. There is a strong demand for compulsory feedback by teachers attending in - service courses. It would appear that there is a strong feeling that there is a lack of links between in - service training and the schools.

The results indicated a dire need for practical work and that practical work should be related to theory. The results further pointed to a need for a sound chemistry background , hence there is a strong feeling that Biochemistry should be introduced as a course to teacher trainees and that chemistry should be a prerequisite for Biology especially higher grade. This points to a need for upgrading of pre - service education. There is however, a move in this direction as the Transkei College of Education due to open in 1990 will be offering degree courses up to Course II level. At present in the schools, 58,1% of the Std 10 and 67,7% of the Std 9 teachers investigated had Matric as their highest academic qualification.

The results of the interviews indicated a need for rearrangement of some topics in the syllabus. There is a

dissatisfaction with the present syllabus as it is seen to be leading pupils nowhere. University lecturers indicated a lack of continuity between what is prescribed for Matric biology and what is prescribed for Botany 1 and Zoology 1, for example. It is unfortunate that Transkei teachers do not have a say in the drawing up of the syllabi. They had to be satisfied with what is prescribed for them by other education departments. In fact for quite some time teachers even in other education departments in South Africa had no say in the drawing up of syllabi, although they are the actual implementers of the syllabi. At least with the new syllabus called a concept or thematic syllabus in biology, teachers from the various departments have had an input although Transkei teachers were again left out.

From the results of the interviews it would appear that the syllabus structure influences learning. The topics in the syllabus therefore should be arranged in a manner that encourages conceptual growth. Teachers also should not follow the textbook as it stands in their teaching. Lessons should be planned and presented in a coherent way. This again points to a need for subject specialisation. It needs a competent teacher to see loop holes in the syllabus and textbooks.

With the background knowledge of teacher qualifications, teacher and pupil problems, the syllabus structure and the poor conditions of schools which are not conducive to learning, a discussion of the results of the concept tests will now be considered.

6.3 CONCEPT TESTS

"HAY - TODAY"

A summary of the percentages of types of responses for the "hay - today" question is given in Table 6.1.

TABLE 6.1

A SUMMARY OF THE PERCENTAGES OF TYPES OF RESPONSES FOR THE QUESTION " HAY - TODAY "

TYPE OF RESPONSE	PERCENTAGE OF TOTAL
	n = 308
1. Responses including only components of the accepted answer	60%
- discussion of light only	25%
- discussion of chlorophyll only	15%
- discussion of sunlight and chlorophyll	12%
- discussion of radiant energy	8%
2. Responses including alternative ideas about plant nutrition	03%
3. Responses including alternative explanations for colour difference	27%
- heat	
- loss of leaves	
- cutting of the grass	
- lack of major nutrients	
- sun	
- shortage of water	
- age	
- conversion of chlorophyll to chromoplast	
- phototropism	
4. Other responses	10%
- No response	7%
- unclassified responses	3%
	100%

The main category in terms of percentage responses was that of responses including components of the accepted answer. 60% of responses were placed in this category as against 30% of responses in Bell's pupils. 27% of responses contained alternative explanations for the colour difference. This appeared to be the main category of responses in Bell's pupils as 42% of responses were placed in this category. One could attribute the large difference (15%) to variations in the syllabus or the level of pupils tested. Responses containing alternative explanations for the colour difference included heat, loss of leaves, cutting of the grass, lack of major nutrients, shortage of water, and age, for example.

It would appear that pupils used their life experiences to answer the question. The loss of the green colour, for example, is linked with what is going to happen to the grass after being cut. Pupils knew that after being cut the grass dries up as it loses moisture, and, consequently will lose the green colour. Further, pupils knew that lack of nutrients, nitrogen, for example, causes plants to lose the green colour. It would appear that pupils knew nitrogen to be one of the components of chlorophyll and if the soil lacks nitrogen, the functioning of chlorophyll will be affected and hence the change from green to yellow. Age also affects the growth of plants. Whether pupils used their everyday experiences or some taught ideas or both it would appear that

they have formulated ideas which they used to answer the question. The ideas are in themselves correct but are not relevant to the question.

A very small percentage 3% of responses contained alternative ideas about plant nutrition. 7% of the sample in this study did not offer an explanation.

VILLAIN

A summary of the percentages of types of responses for the "villain" is provided in Table 6.2.

TABLE 6.2

A SUMMARY OF THE PERCENTAGES OF TYPES OF RESPONSES FOR THE QUESTION : "VILLAIN"

TYPES OF RESPONSE	PERCENTAGE OF TOTAL n = 308
1. Responses including only components of the accepted answer	64%
- chlorophyll, photosynthesis, food and death	19%
- inability to manufacture food and death	12%
- resulting death only	05%
- chlorophyll and photosynthesis	22%
- chlorophyll and death	02%
- loss of green colour	04%
2. Responses including alternative consequences or explanations	20%
- shortage of oxygen	08%
- death of heterotrophs	05%
- inability to grow	03%
- other ideas	04%
3. Alternative ideas on plant nutrition	-
4. Scientifically unacceptable functions of the chlorophyll	06%
5. Other responses	10%
- No response	06%
- unclassified responses	04%

The main category of response to the "villain" question was that of responses including only components of the accepted answer. 64% of responses were placed in this category. Most of the answers however, gave consequences only and no further explanation. Only 19% of the total responses could be considered correct. This does not reflect a sound understanding of the role of chlorophyll as this test was administered to Std 10 pupils. One would expect a better response from Std 10 pupils. Further it could be said that these pupils did not take these tests seriously simply because they were not contributing towards their passing the examinations.

Some responses (22%) focussed mainly on the inability of plants to manufacture food due to lack of chlorophyll. What will eventually happen to plants is overlooked. 12% of the responses mentioned death due to inability to manufacture food. 5% of the responses mentioned the resulting death of plants only, while 4% mentioned the resulting colour change without an explanation. Bell's findings were similar, as she remarked "although the ideas in the answers were in themselves acceptable, the answers were incomplete, without an explanation."

20% of the total responses were placed in the category of responses including alternative consequences or explanations.

Responses included ideas about shortage of oxygen , death of heterotrophs and inability to grow. These ideas are all acceptable but are not relevant to the question. Some ideas referred to as "other ideas" were encountered. These were also acceptable ideas but they had nothing to do with the question.

No responses were placed in the category of alternative ideas on plant nutrition. 6% of the responses were placed in the category of alternative ideas about the role of chlorophyll.

19% of the total responses in Bell's case contained alternative ideas about the role of chlorophyll. Bell thought that since such a category did not arise with the " hay - today" question, the technical term being given might have influenced the responses. With the Transkei pupils, it would appear that the term chlorophyll being given might have given them a clue to answering the question. About 10% of the responses were placed in the category of other responses.

GROW - TREE

A summary of the percentages of responses to the " grow - tree" question is provided in Table 6.3.

TABLE 6.3

A SUMMARY OF THE PERCENTAGES OF TYPES OF RESPONSES FOR THE
QUESTION : "GROW - TREE"

TYPE OF RESPONSE	PERCENTAGE OF TOTAL n = 308
I. Tree grows because of what it takes in from its environment	39%
- water only	
- water and mineral salts	
- soil	
- soil nutrients	
- soil and light	
- water, air and sunlight	
- water and sun	
- water and nutrients	
- radiant energy, air, mineral substances	
- carbon dioxide, water and mineral salts	
- water, mineral salts and sun	
- sunlight, water, carbon dioxide and nutrients	
- mineral salts, carbon dioxide and sunlight	
- oxygen	
2. Growth and development	34%
a) cell division	15%
b) growth hormones	04%
c) growth movements	03%
d) development of tissue	04%
e) maturity	01%
f) secondary thickening	03%
3. Tree grows because of food	13%
a) food manufactured by plant	05%
b) food manufactured by plant and cell division	04%
c) food manufactured by plant and constituents from the environment	04%
4. Tree grows because of food it takes in from the environment	03%
5. Tautology	05%
6. Energy	02%
7. Other Responses	04%

The main category of responses was that the tree grows because of what it takes in from the environment. 39% of the responses were placed in this category. The responses included water, mineral salts, soil, sun, air, carbon dioxide and oxygen. Nutrients was also mentioned. Since there is confusion between organic and inorganic nutrients one is not sure of what the pupils had in mind. Oxygen is mistakenly mentioned as one of the requirements of photosynthesis.

34% of the responses were placed under growth and development. The responses focussed mainly on the mechanisms of growth. No attempts were made to link food with tissue development. 15% of the responses attributed the growth of the tree to cell division. Pupils appeared to have forgotten that cell division occurs after a number of processes, for example, accumulation of nutrients in the cell (photosynthetic end products in this case), synthesis of proteins and DNA, all of which contribute towards the growth of the cell, that is, increase in the size of the cell. It is after these processes that the cell divides contributing to increase in the number of cells.

It would appear that the sequence of topics in the syllabus have had an influence on the responses. Cell division is taught in Std 9 and photosynthesis in Std 10. It would appear therefore that to them, cell division precedes photosynthesis and protein synthesis, or cell division is responsible for growth. Pupils did not appear to know that

the plant is responsible for the synthesis of its structural parts, that is, tissue. There appeared to be no link between food, manufactured during photosynthesis and the role of food as source of energy for a number of metabolic processes.

4% of the pupils tested attributed the growth of the tree to the action of growth hormones, while 3% mentioned growth movements, all of which are mechanisms of growth. 4% of the responses mentioned tissue development, although no link was made between food and development of tissue. 3% of the responses attributed the growth of the tree to secondary thickening, while about 1% mentioned maturity.

In the category of growth and development pupils appeared to have used some taught ideas to answer the question. There appeared to be some missing links as no attempts were made to link these taught ideas to arrive at the accepted answer. The problem is to try to find out what information is lost as concepts derive meaning only through connections with other concepts. If there are missing links "integrative reconciliation" according to Ausubel will not take place.

13% of the responses for the "grow - tree" question were placed in the category - tree grows because of food. Some pupils appeared to know that food has a role to play towards growth. 5% of the responses mentioned food only, while 4% mentioned food and cell division. No attempts however, were made to link food and cell division. 4% of the responses mentioned the constituents the tree obtains from the

environment and the food it manufactures. Some pupils knew that plants get raw materials from the environment to manufacture their own food. On the other hand 4% of the responses contained ideas about heterotrophic feeding instead of autotrophic feeding among green plants. The growth of the tree was attributed to the food it takes in from the environment.

5% of the responses used tautology which did not answer the question at all. 2% attributed the growth of the tree to energy, for example, radiant energy and energy from glycolysis. There was no further explanation. 4% of the responses were placed in the category of other responses.

PHOTOSYNTHESIS CONCEPT TEST

The responses indicated that even some Std 10 pupils showed a poor understanding of the source of food for plants, relationship between photosynthesis and respiration and the role of chlorophyll in photosynthesis. 54,5% of the pupils investigated considered the soil to lose weight, the main reason being that of absorption of water and mineral salts by roots. 66,5% of the pupils tested considered the food of plants to come from the soil. It would appear that the erroneous idea that plants obtain their food from the soil is resistant to change. The results of the two concept tests concerning the source of food for plants confirmed the results obtained by Arnold and Simpson (1982), Roth, Smith and Anderson (1983), Wandersee (1983) and Bell and Brook (1984).

Some of the pupils tested showed a poor perception of the relationship between photosynthesis and animal respiration. Some pupils (40%) placed more importance on food for survival than on oxygen. Further, photosynthesis and respiration were not viewed as complementary processes or else photosynthesis is associated with plants and respiration with animals. Some pupils considered plants to breathe in carbon dioxide and animals breathe in oxygen.

Task 12 investigated pupils understanding of the role of chlorophyll in photosynthesis. A summary of percentages of responses to task 12 is given in Table 5.4.

TABLE 6.4

SUMMARY OF THE PERCENTAGES OF TYPES OF RESPONSES FOR TASK 12 OF THE PCT

TYPE OF RESPONSE	PERCENTAGE OF TOTAL n = 242
1. Responses including only components of the accepted answer	62%
a) discussion of photosynthesis, chlorophyll and sunlight only	15%
b) discussion of photosynthesis and chlorophyll only	24%
c) discussion of chlorophyll and the green pigment (no mention of chlorophyll)	11%
d) discussion of photosynthesis only	03%
e) discussion of chlorophyll, photosynthesis death	04%
f) discussion of colour change and chlorophyll	01%
g) change of season and colour change	04%
2. Alternative ideas for the colour difference	26%
a) water	16%
b) water and sunlight	10%
3. Scientifically unacceptable function of the chlorophyll	07%
- heterotrophic nutrition	
- growth	
- manufacture of food	
4. Other responses	05%
	100%

The main category of responses was that of responses including only components of the accepted answer. 62% of the total responses were placed in this category of responses. 15% of the responses contained ideas about photosynthesis, chlorophyll and sunlight. These appeared to be complete answers as the exact role of chlorophyll was mentioned, for example, "the leaf can no longer manufacture its own food because it has lost chlorophyll, and the leaf can't trap radiant energy from the sun. 24% of the responses placed in this category contained ideas about photosynthesis and chlorophyll only - the role of chlorophyll is not mentioned. 11% of the responses mentioned photosynthesis and the green pigment without any mention of chlorophyll. About 3% of the responses contained ideas about the leaf's inability to manufacture food without any reasons for this malfunction.

In this task the term "chlorophyll" was not mentioned as was the case with the "villain" question. One could therefore infer that the technical term being given had helped the respondents. In Wandersee's study about 24% of responses across all grades mentioned the word chlorophyll. It was not expected of Std 10 pupils to keep on referring to the "green pigment" or "green colour" instead of chlorophyll.

In fall, the chlorophyll of many plants disintegrates. As a result, the more stable accessory pigments, for example, the "carrot - red" to "butter - yellow" carotenoids and bright yellow to brownish xanthophylls, become unmasked and give rise to the brilliant colours of Autumn foliage. (Weisz and Keogh 1982).

There is no mention of other pigments found in plants which are masked by the green colour of chlorophyll. The pupils may be aware of them but did not think about them at the time of answering the test.

26% of the total responses were placed in the category of alternative ideas or explanations for the colour difference. Responses included, for example, shortage of water and inadequate sunlight. The responses did not mention the role of chlorophyll in photosynthesis. The colour difference is explained in terms of shortage of water(16%) and inadequate sunlight . Shortage of water does lead to colour change and drying but such responses do not explain the role of chlorophyll. However it is quite interesting to note how pupils can use their life experiences to explain some phenomena. Pupils appeared to observe seasonal changes, for example, they knew that deciduous trees shed leaves in Winter and since rain falls mainly in Summer, there will be shortage of water in Autumn and Winter which could lead to drying of leaves and change of colour.

7% of the responses indicated a lack of understanding of the function of chlorophyll. Some responses contained ideas about heterotrophic feeding. It appeared that some pupils held the view that plants make food for animals and not for themselves. This confirms the remark by Arnold and Simpson (1982), that the classification of green plants as producers and animals as consumers is misleading and can reinforce the misconception that plants get their food from the environment instead of manufacturing it. Some responses mentioned chlorophyll as being responsible for manufacturing the food for plants.

About 5% of the total responses were placed in the category of other responses.

6.4 CONCEPT MAPS

The concept maps drawn by pupils indicated that concept maps could be used to test pupils' understanding of concepts. They showed that pupils' understanding of concepts differ. Since concept mapping is used to show relationships between ideas (Novak and Gowin 1985) it has proved to be a useful method of testing how pupils relate different ideas in photosynthesis and protein synthesis, for example.

6.5 CONCLUSION

This study has confirmed the fact that pupils have formulated ideas about phenomena occurring in the physical world; that these ideas differ and have been found to influence learning.

These ideas have been referred to as alternative frameworks, alternative conceptions etc. Some of these ideas have been found to be resistant to change and have been referred to as misconceptions.

The concept tests have indicated that although these pupils had received formal teaching in photosynthesis only a few of these pupils use these ideas correctly. The responses by some pupils indicated that they used their everyday experiences to answer the questions. This therefore means that by the time pupils receive formal teaching in photosynthesis they have formulated "intuitive ideas" about the process. Photosynthesis is taught in Std 10 and by the time pupils are taught it formally, they have been influenced by their gardening experiences, societal practices and everyday language use. The situation becomes worse if one's own language has limitations.

In Xhosa, for example, there are instances where there is only one word for a number of different terms. For example, there is only one word in Xhosa for heat and temperature, blue and green, energy and power, melt and dissolve. This supports Streven's view that problems are likely to occur if the vehicle of instruction is not one's mother tongue. At the same time it can never be used to explain science concepts. Language therefore is bound to influence pupils' interpretation of phenomena.

Research by Erickson (19) has indicated that pupils have problems with the concepts heat and temperature. Research by Watts (1983) has pointed to some alternative views pupils have about the concept, energy. Pupils' understanding of energy and energy conversion is essential to the understanding of photosynthesis, that is, conversion of light energy to chemical potential energy.

The responses also indicated that pupils can use taught ideas in answering the questions. It therefore means that pupils use both their "intuitive ideas" and some taught ideas and the result is a mixture of taught ideas and "intuitive ideas. The questionnaires and interviews indicated teacher problems in the subject, so the taught ideas may also be incorrect. Mibiol (198) remarked that misconceptions in photosynthesis and respiration are reinforced by teachers because they do not exist in one's own language. This could be true if the teacher does not understand the two processes.

The findings suggest that the ideas held by pupils have to be taken into consideration by teachers. The teacher should act as a facilitator of knowledge and not a transmitter of knowledge. Teaching should be geared towards helping each pupil to develop his or her own ideas. Pupils should therefore be exposed to learning activities which actively involve them. More time should therefore be allocated to

some practical investigations, and class discussions. There is a need for nurseries or even gardens in schools where pupils could be involved in small projects which could lead to better understanding of plant nutrition and other related topics like plant water relations, animal nutrition, energy transformations, and biological compounds, for example.

The results of the interviews and questionnaires indicated a need for a sound chemistry background. An understanding of the particulate nature of matter, for example, can be considered a prerequisite to a better understanding of photosynthesis. Photosynthesis needs to be treated from the molecular level of organisation if one is to understand the movement of water and gas particles, and of the conversion of light energy to chemical energy. Difficulties in understanding photosynthesis and plant water relations are in part attributable to pupils' alternative ideas about matter and energy conservation. This particle nature of matter as it is named in Transkei textbooks, is also a problem to underqualified teachers.

In Transkei schools the particle nature of matter is dealt with in Stds 6 and 7 at an elementary level. Nothing is said about the particle nature of light. It is doubtful if the background knowledge gained at this level or even at Std 9 level fully equips the child for the understanding of photosynthesis and other biochemical processes.

6.6 RECOMMENDATIONS

The findings point to a need for restructuring of pre - service and in - service education.

Teacher trainees should be introduced to teaching strategies which take into account the ideas pupils bring to their classes, as these have been found to influence learning. The constructivist view of learning places emphasis on the role the pupils' concepts play in the construction of meaning. Concept maps concept tests and other strategies which are aimed at concept development should be introduced to teacher trainees. Concept maps are useful tools to assess pupils' understanding of concepts. Through use of concept maps pupils get a chance of discussing their ideas. They begin to appreciate the fact that different persons hold different views and that their views serve as starting points in learning. Knowing that their ideas are respected they will be free to discuss them with their peers or teachers and will not be offended when corrected. Small groups can be formed to ensure participation by all members in the group. Concept maps can be used by pupils to summarise lessons and to write laboratory reports and results of field studies.

These strategies should not only be introduced to teacher trainees but also to teachers in service. Through use of concept maps teachers will be in a better position of assessing the effectiveness of their lessons. Instead of using tests which call for reproduction of taught ideas concept tests should be used as teachers will be in a better position to uncover the alternative ideas pupils hold about particular topics.

There should be co - ordination between pre - service training and in - service training of teachers to ensure uniformity of approach in the handling of the subject.

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APPENDIX IQUESTIONNAIRE TO SENIOR SECONDARY SCHOOL PUPILS

PLEASE READ THE FOLLOWING BEFORE ANSWERING THE QUESTIONNAIRE

1. It is not necessary to write your name or sign the questionnaire.
2. This questionnaire is part of a study of identifying some of the problems of senior secondary school pupils in some aspects of Biochemistry. The study also seeks to look into the ways in which these problems influence the performance of pupils in Biology. It is hoped that the responses to the questionnaire will help to solve some of these problems.
3. Use a pencil to mark your answers on the questionnaire. Circle the code which best corresponds to your answers.
For example: What is your sex?
 1. MALE
 - ② FEMALE
4. Please give answers in writing in questions where you are asked to do so. For example: Give reasons for your answer
.....
5. Please make every answer a sincere one.

THANK YOU FOR YOUR CO-OPERATION AND ASSISTANCE.

1. What is the name of your school?
2. What is your sex?
 1. MALE
 2. FEMALE
3. What is your age?
 1. Less than 13 years
 2. 13 - 15 years
 3. 16 - 18 "
 4. 19 - 21 "
 5. Above 21 "
4. What class are you doing this year?
 1. Std 9
 2. Std 10
5. Are you studying Physical Science this year?
 1. YES
 2. NO
6. If No, did you do Physical Science in Std 8?
 1. YES
 2. NO
7. What symbol did you obtain in Physical Science in Std 8?

1. A	6. F
2. B	7. G
3. C	8. H
4. D	9. other, specify
5. E	
8. What symbol did you obtain in Biology in Std 8?

1. A	6. F
2. B	7. G
3. C	8. H
4. D	9. other, specify
5. E	

9. The following is the list of Biochemistry topics as laid down by the New syllabus, mark 3 sections you find easy and 3 you find most difficult.

- 1. Chemical composition of protoplasm.
- 2. Relevant functions of water and proteins.
- 3. Nucleic Acids.
- 4. protein synthesis and gene mutation.
- 5. Biological compounds and nutrients - water, macro and micronutrients; organic compounds - carbohydrates, lipids, proteins; vitamins.
- 6. Enzymes and Co-enzymes
- 7. photosynthesis
- 8. Cellular respiration
- 9. Chemical processes of digestion

10. Explain why you find the three topics easy.

.....

.....

11. Explain why you find the three topics difficult.

.....

.....

12. Do you find the language used in teaching Biochemistry difficult?

- 1. YES
- 2. NO

13. If YES, can you give reasons

.....

.....

.....

14. Do you think that it is the language of the teacher that causes your problems in Biochemistry?

- 1. YES
- 2. NO

For official
use

19. Do you wish to study Biochemistry at University level?

1. YES

2. NO

20. if YES, give reasons

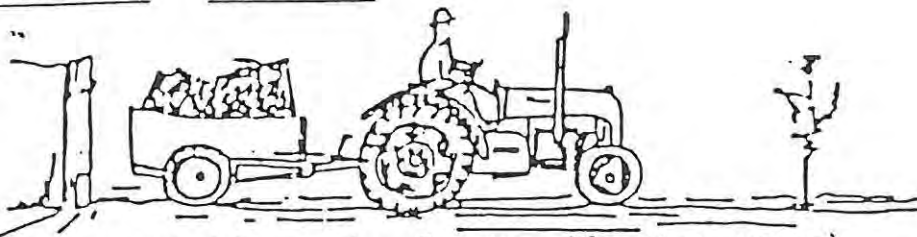
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.....

21. If NO, give reasons

.....
.....

Can you please answer the following questions:

Question 1 Hay-today



A farmer cut his meadow for hay (feeding grass).
 He noticed that the grass he cut was green, but
 the stalks left were yellow.
 How do you explain this?

.....

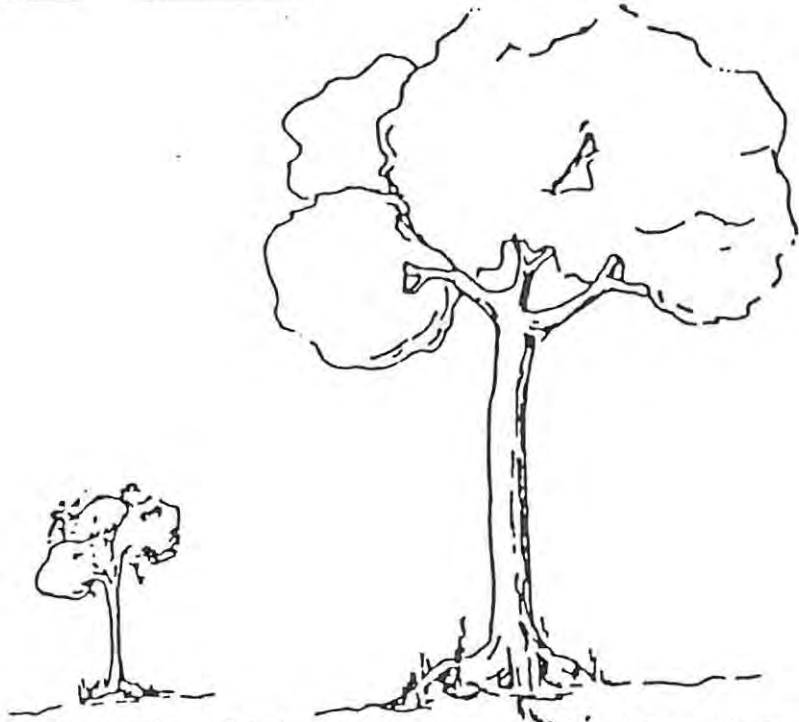
Question 2 Villain

In a science fiction book, a villain (wrong-doer)
 threatens to spray the countryside with a chemical
 that destroys chlorophyll (the green substance in
 plants) ..

What effect will this have on plant life? Explain
 your answer as fully as you can.

.....

Question 3 Grow Tree



A small tree is planted in a meadow. After 20 years it has grown into a big tree, weighing 250 kg more than when it was planted.

Where do the extra 250 kg come from? Explain your answer as fully as you can.

.....
.....
.....
.....

PHOTOSYNTHESIS CONCEPT TEST

PROBLEM I

Use what you know about plants to solve the following puzzles :
Read the story in drawings (a), (b) and (c)

A green plant weighed 1 kg without any soil on its roots. It was planted in a tub of soil. The experimenter watered the plant whenever the soil was dry but did nothing else.

a)



After the plant had grown for 5 years she removed the plant from the tub and weighed it again. The plant now weighed 17 kg.

b)



What do you think must have happened to the weight of the soil in the tub after the plant grew in it for 5 years and gained much weight?

c)



Task, No 1

Place an X in the square next to the sentence you think best describes what happened.

- [] The soil lost a lot of weight
- [] The soil's weight stayed about the same
- [] The soil gained a lot of weight

Task No 2

Explain why you picked the answer you did.

PROBLEM III

Most plants have green leaves. What is the main function of a leaf?

Task No 6

Place an X in the square next to the function you choose as answers to the question. Mark only one square.

- [] leaves serve to shade the tender young shoots of the plant from the hot sun
 [] leaves catch the rain and dew plants need to live
 [] leaves make food that keeps the plant alive
 [] leaves capture the warmth of the sun

Task No 7

Someone has said that leaves "breathe". Even though this is not strictly true (leaves do not have lungs) you may understand what he is trying to say. If the following substances go in and out of the leaf, show which direction each substance travels (in or out)

Substance :	IN	OUT	
Carbon dioxide	[]	[]	use check marks (ticks) to indicate your answer.
Water vapour	[]	[]	
Oxygen	[]	[]	

PROBLEM IV

Like animals plants need food in order to stay alive. If you were asked where most of the food in plants comes from which of the following would you consider to be the best answer? Mark one

Task No 8

Place an X in square next to your choice.

- [] The food of plants comes from water
 [] The food of plants comes from carbon dioxide
 [] The food of plants comes from soil
 [] The food of plants comes from water and air

Task No 9

Explain why you picked the answer you did.

PROBLEM V

Two plants of the same kind and size are put in two different places. One is put on a closed shelf and one is placed on a window sill. After one month both plants are brought back into a lighted room (both plants had been kept watered)

Task No 10

Draw a picture of each plant in its pot as you think it would look



CLOSED PLANT



WINDOW PLANT

PROBLEM VI

You may have heard of the leaf called a "factory". All factories make a product. If you had to mention the products a leaf makes, which of the following would you select?

Task No 11

Place an X in the square next to the best answer

- [] proteins
 [] fats
 [] carbohydrates

PROBLEM VII

In late summer and early fall (Autumn) the leaves of many common trees change colour from green to red; orange, yellow or brown. Although this colour change is beautiful for us to observe, how does the loss of its green chemical affect the leaf's main function?

Task No 12

Complete the statement below in your own words

The leaf can no longer _____

_____ because

THE END

APPENDIX IV

TRINSET BIOGRAPHICAL QUESTIONNAIRE

(our ref: biograph)

Course No..... Date..... Leader.....

Please complete neatly and accurately. All information is for internal use and will be kept confidential.

Part I on the first day, and Part II at the end of the course.

Part I

SURNAME:.....(Mr, Mrs, Miss ?)....

FIRST NAMES:.....

NAME AND FULL ADDRESS OF PRESENT SCHOOL :.....

YOUR RANK:.....

SCHOOL TELEPHONE NUMBER & CODE:.....

CURRENT TEACHING DUTIES (Main subject first)

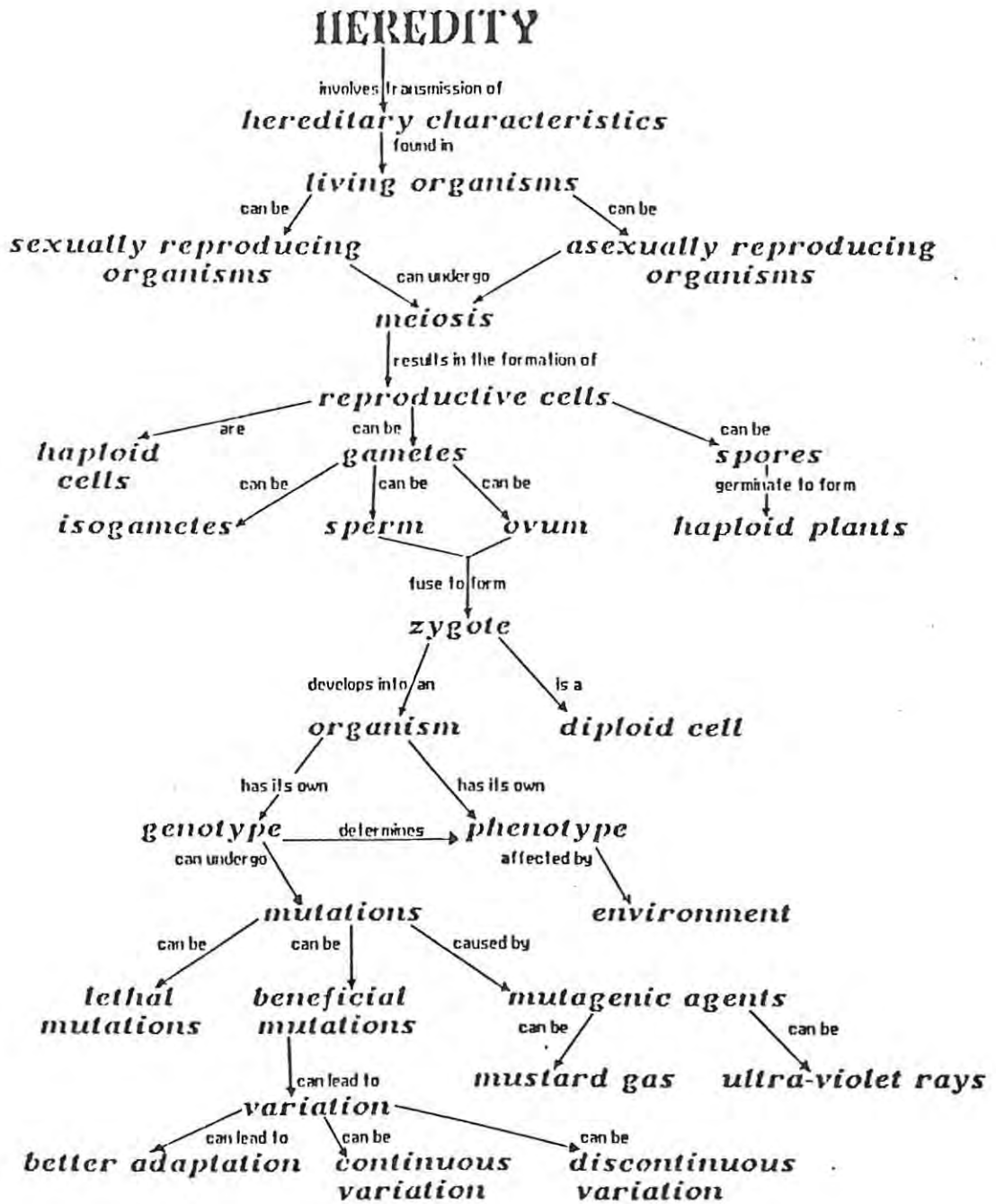
Table with 3 columns: Subject Taught, In which standards?, Experience in years. (in this subject). Rows 1, 2, 3.

EDUCATIONAL QUALIFICATIONS

School - Highest Standard passed
College - Teachers' Diploma(s)
University - Degree(s)/Courses

Are you presently studying for any additional qualifications ?

If so, what are you studying ?



PROTEIN SYNTHESIS

