# CHAPTER FOUR: RESULTS – QUANTITATIVE DATA

## 4.1. INTRODUCTION

This chapter seeks to use quantitative data to help to answer research questions 2 and 3:

(2) How do learners in the Gauteng province of South Africa experience the transition from Natural Science in the GET phase to Physical Science in the FET phase.

(3) How can the learners' strategies and approaches for negotiating the transition be understood and explained?

**Firstly the results of the grade 11 Physical Science examinations:**
The achievements of boys and girls in the grade 11 Physical Science final examinations were compared. I then classified learners as high achievers and low achievers on the basis of their achievement and used the examination marks as a baseline to compare interest and epistemological beliefs.

**Secondly the results of the interest questionnaire:**
Firstly, the reliability of the interest questionnaire was determined. Next I compared the interest in the various sciences in grade 9 according to gender. Then I explored the change in interest in Physical Science as learners moved from GET to FET. Lastly, I explored correlation between interest shown in Physical Science and achievement in the grade 11 Physical Science examinations.

**Thirdly the results of the NOS survey:**
The NOS survey was used to investigate the learners' scientific epistemological inclinations. I did this by classifying them as empiricist-aligned or post-positivist oriented, on the basis of their scores on the NOS survey. Statistical analysis of the responses to the NOS questionnaire was then carried out to find out if there was a correlation between the NOS scores and achievement in the Physical Science examination. The analysis also explored if there were

differences across gender and between the Physical Science and non-Physical Science learners.

**Finally the results of the diagnostic test:**

The test was administered to assess the content knowledge that the FET learners acquired as well as their strategies for solving conceptual problems.

## 4.2 THE GRADE 11 EXAMINATION

The examination marks used in this study are those obtained from the 2007 grade 11 Physical Science Paper 2 (Chemistry) examination obtainable from the Department of Education (DoE) website www.education.gov.za. Refer also to the weighting of the Learning Outcomes and examination content for grade 11 Physical Science in Appendix K. The results of the 2007 grade 11 Physical Science paper 2 (Chemistry) are summarized in Table 4.1(a). The $v_1$ number is the reference number of the learner who wrote the examination.

Table 4.1(a) Achievement in the 2007 grade 11 Physical Science examinations (Chemistry)

| $V_1$ | Gender | Exam marks (%) |
|---|---|---|
| 0026 | F | 20 |
| 0029 | F | 24 |
| 0074 | F | 30 |
| 0145 | F | 30 |
| 0150 | F | 30 |
| 0160 | F | 30 |
| 0142 | F | 31 |
| 0070 | F | 32 |
| 0107 | F | 32 |
| 0149 | F | 32 |
| 0151 | F | 32 |
| 0162 | F | 32 |
| 0021 | F | 33 |
| 0072 | F | 33 |
| 0125 | F | 33 |
| 0146 | F | 33 |
| 0027 | F | 34 |
| 0061 | F | 34 |
| 0101 | F | 34 |
| 0158 | F | 34 |
| 0047 | F | 35 |
| 0130 | F | 36 |
| 0105 | F | 36 |
| 0141 | F | 37 |
| 0050 | F | 39 |
| 0147 | F | 39 |
| 0154 | F | 39 |
| 0076 | F | 49 |
| 0117 | F | 60 |
| 0073 | M | 32 |
| 0063 | M | 33 |
| 0152 | M | 33 |
| 0049 | M | 34 |
| 0013 | M | 36 |
| 0102 | M | 39 |
| 0001 | M | 48 |
| 0086 | M | 48 |
| 0038 | M | 50 |
| 0039 | M | 50 |
| 0058 | M | 51 |

Neither I nor the teacher set the examination. It was a national examination. Girls were in the great majority (29 out of 40). The performance was dismal, with only four learners obtaining 50% or more. Table 4.1 (b) shows that the average score for boys is about 7% more than that for girls.

Table 4.1 (b) Descriptive statistics on the Physical Science examination

| Variable | N | Mean | SD | Sum | Min | Max |
|---|---|---|---|---|---|---|
| Boys | 11 | 41.27 | 8.04 | 454 | 32 | 51 |
| Girls | 29 | 34.24 | 7.03 | 993 | 20 | 60 |

Was this difference statistically significant? The null hypothesis that had to be tested was:
*There is no significant difference between the examination scores of boys and of girls in the Physical Science examination.*

The two-tail t-test revealed that the difference between the examination scores of boys and girls was indeed statistically significant, with p= 0.0099.

## 4.3 THE INTEREST QUESTIONNAIRE (IQNSFS)

For each item, learners had to indicate on a scale of 0 to 3 how much they would like to do the relevant activity to measure interest in each of the subjects Physical Science, Life Sciences, Mathematics and Computer Science. The preferred response was to be indicated by using the following code:

0 = Would never do it
1 = Don't like it , but may do it
2 = Like it slightly
3 = Like it very much

The interest questionnaire (given in Appendix A) was administered to 417 learners, 3 short of the intended number of 420. Table 4.2 shows the number of grade 9 learners in the sample: the intended number of learners, the number of questionnaires that were either used or spoilt, the actual number of questionnaires used in the study and the percentage usable

questionnaires. The unused questionnaires reflected the fact that some learners were absent on the day the questionnaires were administered, or they were simply not returned.

Table 4.2 The number of grade 9 learners in the sample.

| Participating school | Intended sample: number of learners | Number of questionnaires unused/spoilt | Actual sample: number of questionnaires used in the study | | | % usable questionnaires |
|---|---|---|---|---|---|---|
| | Total | Total | Boys | Girls | Total | % |
| A | 162 | 0 | 66 | 96 | 162 | 100 |
| B | 258 | 3 | 117 | 138 | 255 | 99 |
| TOTAL | 420 | 3 | 183 | 234 | 417 | 99 |

### 4.3.1 Reliability of the interest questionnaire

To know more about the contribution of an item to the subject to which it belongs, Tables 4.3 to 4.6 show correlation of scores for test items within each of the subjects Physical Science, Life Sciences, Mathematics and Computer Science. The Cronbach alpha coefficients were used for this purpose (Swanepoel, 1986). The V numbers in the tables are the reference number of the items in the questionnaire.

Table 4.3 Correlation and reliability of items for Physical Science

| Item number | V number | Cronbach's alpha-coefficient | | |
|---|---|---|---|---|
| | | Overall | Boys | Girls |
| 1 | v3 | 0.852 | 0.859 | 0.846 |
| 4 | v6 | 0.855 | 0.861 | 0.848 |
| 5 | v7 | 0.854 | 0.861 | 0.848 |
| 14 | v16 | 0.852 | 0.857 | 0.847 |
| 19 | v21 | 0.850 | 0.852 | 0.847 |
| 20 | v22 | 0.850 | 0.852 | 0.846 |
| 23 | v25 | 0.848 | 0.850 | 0.847 |
| 29 | v31 | 0.845 | 0.847 | 0.843 |
| 32 | v34 | 0.846 | 0.848 | 0.842 |
| 35 | v37 | 0.850 | 0.857 | 0.845 |
| 37 | v39 | 0.845 | 0.848 | 0.842 |
| 43 | v45 | 0.849 | 0.856 | 0.843 |
| 48 | v50 | 0.852 | 0.857 | 0.848 |
| 52 | v54 | 0.847 | 0.854 | 0.841 |
| 59 | v61 | 0.845 | 0.850 | 0.840 |
| 63 | v65 | 0.849 | 0.856 | 0.842 |
| 69 | v71 | 0.850 | 0.855 | 0.844 |
| 70 | v72 | 0.847 | 0.853 | 0.842 |
| 77 | v79 | 0.845 | 0.850 | 0.840 |
| 81 | v83 | 0.843 | 0.847 | 0.838 |
| 84 | v86 | 0.845 | 0.853 | 0.838 |

The consistently high Cronbach alpha-coefficient for the items in Physical Science in Table 4.3 showed that none of the items in Physical Science had to be rejected from the questionnaire – the test was internally consistent.

Table 4.4 Correlation and reliability of items for Life Sciences

| Item number | V number | Cronbach's alpha-coefficient | | |
|---|---|---|---|---|
| | | Overall | Boys | Girls |
| 6 | v8 | 0.882 | 0.887 | 0.879 |
| 10 | v12 | 0.881 | 0.884 | 0.879 |
| 11 | v13 | 0.880 | 0.885 | 0.877 |
| 15 | v17 | 0.880 | 0.885 | 0.877 |
| 17 | v19 | 0.883 | 0.887 | 0.880 |
| 22 | v24 | 0.883 | 0.887 | 0.881 |
| 26 | v28 | 0.882 | 0.886 | 0.879 |
| 33 | v35 | 0.882 | 0.888 | 0.878 |
| 38 | v40 | 0.879 | 0.886 | 0.873 |
| 41 | v43 | 0.878 | 0.885 | 0.873 |
| 44 | v46 | 0.878 | 0.884 | 0.873 |
| 45 | v47 | 0.880 | 0.885 | 0.877 |
| 53 | v55 | 0.877 | 0.882 | 0.873 |
| 55 | v57 | 0.879 | 0.885 | 0.873 |
| 62 | v64 | 0.879 | 0.884 | 0.876 |
| 67 | v69 | 0.879 | 0.886 | 0.873 |
| 71 | v73 | 0.879 | 0.883 | 0.876 |
| 74 | v76 | 0.878 | 0.882 | 0.875 |
| 76 | v78 | 0.878 | 0.884 | 0.872 |
| 80 | v82 | 0.878 | 0.884 | 0.873 |
| 83 | v85 | 0.877 | 0.884 | 0.872 |

Table 4.4 also showed high reliability coefficients. The consistently high Cronbach alpha-coefficients for the items in Life Sciences in Table 4.4 showed that none of the items in Life Sciences had to be rejected from the questionnaire – the test was internally consistent.

Table 4.5 Correlation and reliability of items for Mathematical Sciences

| Item number | V number | Cronbach's alpha-coefficient | | |
|---|---|---|---|---|
| | | Overall | Boys | Girls |
| 2 | v4 | 0.867 | 0.871 | 0.864 |
| 7 | v9 | 0.871 | 0.875 | 0.870 |
| 9 | v11 | 0.865 | 0.870 | 0.862 |
| 12 | v14 | 0.865 | 0.869 | 0.864 |
| 18 | v20 | 0.868 | 0.873 | 0.866 |
| 25 | v27 | 0.861 | 0.867 | 0.858 |
| 28 | v30 | 0.862 | 0.869 | 0.858 |
| 31 | v33 | 0.874 | 0.879 | 0.871 |
| 34 | v36 | 0.868 | 0.873 | 0.865 |
| 42 | v44 | 0.867 | 0.874 | 0.863 |
| 47 | v49 | 0.865 | 0.870 | 0.862 |
| 50 | v52 | 0.858 | 0.862 | 0.857 |
| 51 | v53 | 0.865 | 0.873 | 0.861 |
| 56 | v58 | 0.866 | 0.873 | 0.862 |
| 58 | v60 | 0.860 | 0.867 | 0.856 |
| 61 | v63 | 0.863 | 0.871 | 0.858 |
| 66 | v68 | 0.866 | 0.870 | 0.863 |
| 72 | v74 | 0.860 | 0.865 | 0.857 |
| 75 | v77 | 0.859 | 0.865 | 0.855 |
| 78 | v80 | 0.866 | 0.872 | 0.861 |
| 82 | v84 | 0.859 | 0.865 | 0.855 |

The consistently high Cronbach alpha-coefficient for the items in Mathematical Sciences in Table 4.5 showed that none of the items in Mathematical Sciences had to be rejected from the questionnaire – the test was internally consistent.

Table 4.6 Correlation and reliability of items for Computer Sciences

| Item number | V Number | Cronbach's alpha-coefficient | | |
|---|---|---|---|---|
| | | Overall | Boys | Girls |
| 3 | v5 | 0.865 | 0.882 | 0.849 |
| 8 | v10 | 0.864 | 0.881 | 0.848 |
| 13 | v15 | 0.862 | 0.882 | 0.842 |
| 16 | v18 | 0.861 | 0.877 | 0.845 |
| 21 | v23 | 0.860 | 0.879 | 0.842 |
| 24 | v26 | 0.861 | 0.877 | 0.845 |
| 27 | v29 | 0.864 | 0.880 | 0.848 |
| 30 | v32 | 0.857 | 0.875 | 0.840 |
| 36 | v38 | 0.856 | 0.876 | 0.836 |
| 39 | v41 | 0.860 | 0.878 | 0.843 |
| 40 | v42 | 0.858 | 0.877 | 0.840 |
| 46 | v48 | 0.861 | 0.879 | 0.843 |
| 49 | v51 | 0.859 | 0.876 | 0.841 |
| 54 | v56 | 0.862 | 0.882 | 0.843 |
| 57 | v59 | 0.857 | 0.876 | 0.839 |
| 60 | v62 | 0.857 | 0.875 | 0.840 |
| 64 | v66 | 0.861 | 0.882 | 0.840 |
| 65 | v67 | 0.861 | 0.879 | 0.843 |
| 68 | v70 | 0.860 | 0.880 | 0841 |
| 73 | v75 | 0.867 | 0.885 | 0.850 |
| 79 | v81 | 0.861 | 0.881 | 0.843 |

Table 4.6 showed a consistently high reliability coefficient for Computer Science items. The high Cronbach alpha-coefficient for the items in Computer Sciences in Table 4.6 showed that none of the items in Computer Sciences had to be rejected from the questionnaire – the test was internally consistent.

### 4.3.2 Subject preferences of grade 9 learners

Arithmetic means and medians form the basis of item analysis (Table 4.7) to determine the level of interest shown by boys and girls in the different subjects. This table should be studied in conjunction with Appendix B which indicates the number of respondents for each item.

Table 4.7 The arithmetic means, standard deviations and medians according to subject and gender

| Subject | Gender | Total number | Arithmetic mean | Standard deviation | Median |
|---|---|---|---|---|---|
| PS | Overall | 417 | 1.74 | 0.49 | 1.76 |
| | Boys | 183 | 1.79 | 0.51 | 1.81 |
| | Girls | 234 | 1.70 | 0.48 | 1.70 |
| LS | Overall | 417 | 1.70 | 0.52 | 1.71 |
| | Boys | 183 | 1.69 | 0.53 | 1.67 |
| | Girls | 234 | 1.71 | 0.51 | 1.71 |
| MS | Overall | 417 | 1.82 | 0.53 | 1.86 |
| | Boys | 183 | 1.81 | 0.54 | 1.86 |
| | Girls | 234 | 1.83 | 0.52 | 1.83 |
| CS | Overall | 417 | 2.35 | 0.44 | 2.43 |
| | Boys | 183 | 2.39 | 0.46 | 2.48 |
| | Girls | 234 | 2.31 | 0.43 | 2.31 |

So, using a scale that ranges from 0 to 3, the midpoint would be 1.5. It is clear from Table 4.7 that the arithmetic means and the medians are all above 1.5. So there was no aversion for any particular subject.

Having shown that each one of the 4 tests measuring interest in a specific subject was internally consistent, I proceeded with the formulation of the null hypotheses.

It was important first to find out if there was any significant difference between boys and girls with regard to their interest in the different subjects. If there was a significant difference between boys and girls with regard to interest in the different subjects, then parallel studies,

one for boys and another one for girls, wouldl have to be conducted to determine how learners experience transition from GET to FET.

The following null hypotheses were formulated:

- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Physical Sciences.*
- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Life Sciences.*
- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Mathematical Sciences.*
- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Computer Sciences.*

The null hypotheses were tested using a t-test and the results captured in Table 4.8.

Table 4.8 T-test comparison of boys' and girls' interest in scientific subjects

| Subject | t-value | p-value |
|---|---|---|
| Physical Science | 1.81 | 0.0708 |
| Life Science | -0.57 | 0.5672 |
| Mathematical Science | -0.47 | 0.6407 |
| Computer Science | 1.72 | 0.0867 |

Table 4.8 indicates that the null hypotheses could not be rejected. In particular:

- *There is a tendency to differ between grade 9 boys and girls with regard to interest shown for Physical Science. Table 4.7 shows that there is a higher arithmetic mean for boys. The t-test, however, shows that this difference is statistically insignificant because the p-value is slightly greater than 0.05.*

- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Life Sciences (p value > 0.05). Table 4.7 shows a higher arithmetic mean for girls, but the t-test reveals that this difference is statistically insignificant.*

- *There is no significant difference between grade 9 boys and girls with regard to interest shown for Mathematical Sciences (p value > 0.05). Table 4.7 shows a higher arithmetic mean for girls but the t-test reveals that this difference is not statistically significant.*

- *There is a tendency to differ between grade 9 boys and girls with regard to interest shown in Computer Sciences. Table 4.7 shows that there is a higher arithmetic mean for boys. The t-test, however, shows that this difference is not statistically significant because the p-value is slightly greater than 0.05.*

### 4.3.3 Change in interest from grade 9 to grade 10

Table 4.9 compares the mean scores of the interest test in Physical Science of the learners when they were in grade 9 to those when they were in grade 10. Results are shown separately for boys and girls.

Clearly, interest in Physical Science increased for girls, boys and the overall group during their transition from grade 9 to grade 10. The question arose, were these increases significant?

Table 4.9 Change in average scores in the Physical Science Interest questionnaire for learners when progressing from grade 9 to grade 10

| | Number | Grade 9 average | Grade 10 average | Increase |
|---|---|---|---|---|
| Boys | 16 | 1.62 | 2.06 | 0.44 |
| Girls | 45 | 1.88 | 1.97 | 0.09 |
| Overall | 61 | 1.81 | 1.99 | 0.18 |

The following null hypotheses were formulated:

- *There is no significant difference between boys in grade 9 (GET) and the same boys in grade 10 (FET) with regard to interest shown for Physical Science.*

- *There is no significant difference between girls in grade 9 (GET) and the same girls in grade 10 (FET) with regard to interest shown for Physical Science.*
- *There is no significant difference between learners in grade 9 (GET) and the same cohort of learners in grade 10 (FET) with regard to interest shown for Physical Science.*

The hypotheses were tested and the results given in Table 4.10

Table 4.10 T-test comparison of interest in Physical Science in grade 9 and grade 10

| Sample | Number of learners | t-value | p-value |
|---|---|---|---|
| Overall | 61 | 2.69 | 0.0092 |
| Boys | 16 | 2.74 | 0.0153 |
| Girls | 45 | 1.35 | 0.1845 |

Table 4.10 indicates that:

- There is a significant difference between boys in grade 9 (GET) and the same boys in grade 10 (FET) with regard to interest shown for Physical Science ($p < 0.05$). Table 4.9 does indicate an increase in interest in Physical Science as boys moved from grade 9 to grade 10. Table 4.10 shows that this difference is indeed significant.
- There is no significant difference between girls in grade 9 (GET) and the same girls in grade 10 (FET) with regard to interest shown for Physical Science ($p > 0.05$). Although Table 4.9 indicates a slight increase in interest in Physical Science as girls moved from grade 9 to grade 10, this difference is not significant (Table 4.10).
- There is a significant difference between learners in grade 9 (GET) and the same cohort of learners in grade 10 (FET) with regard to interest shown for Physical Science ($p < 5$). Table 4.9 does indicate an increase in interest in Physical Science as all learners together moved from grade 9 to grade 10. Table 4.10 shows that this difference is indeed significant.

### 4.3.4 Correlation between achievement in the grade 11 examinations and interest

A possible correlation between interest and performance in Physical Science was explored to shed light on learners' experiences and coping with the transition. Table 4.11 shows the scores in

Table 4.11 Interest in Physical Science versus achievement in the Physical Science examinations

| $V_1$ | Gender | Exam marks (%) | Interest (max 63) |
|---|---|---|---|
| 0026 | F | 20 | 37 |
| 0029 | F | 24 | 36 |
| 0074 | F | 30 | 47 |
| 0145 | F | 30 | 51 |
| 0150 | F | 30 | 41 |
| 0160 | F | 30 | 51 |
| 0142 | F | 31 | 40 |
| 0070 | F | 32 | 42 |
| 0107 | F | 32 | 40 |
| 0149 | F | 32 | 48 |
| 0151 | F | 32 | 44 |
| 0162 | F | 32 | 42 |
| 0073 | M | 32 | 56 |
| 0021 | F | 33 | 51 |
| 0072 | F | 33 | 35 |
| 0125 | F | 33 | 46 |
| 0146 | F | 33 | 52 |
| 0063 | M | 33 | 39 |
| 0152 | M | 33 | 58 |
| 0027 | F | 34 | 27 |
| 0061 | F | 34 | 53 |
| 0101 | F | 34 | 51 |
| 0158 | F | 34 | 35 |
| 0049 | M | 34 | 57 |
| 0047 | F | 35 | 54 |
| 0130 | F | 36 | 35 |
| 0105 | F | 36 | 54 |
| 0013 | M | 36 | 50 |
| 0141 | F | 37 | 39 |
| 0050 | F | 39 | 55 |
| 0147 | F | 39 | 59 |
| 0154 | F | 39 | 56 |
| 0102 | M | 39 | 45 |
| 0001 | M | 48 | 49 |
| 0086 | M | 48 | 36 |
| 0076 | F | 49 | 41 |
| 0038 | M | 50 | 60 |
| 0039 | M | 50 | 31 |
| 0058 | M | 51 | 60 |
| 0117 | F | 60 | 34 |

the grade 11 examinations as well as in the interest questionnaire. The Interest score in Table 4.11 was calculated for Physical Science only. It was calculated by adding all the scores for each Physical Science item. The possible maximum score was 63 (3 x 21 Physical Science items).

The following null hypothesis was formulated:

*There is no significant correlation between interest in Physical Science and achievement in the Physical Science examinations.*

Descriptive statistics on interest and examination score are displayed in Table 4.12 and a scatter-plot is shown in Figure 4.1.

Table 4.12: Descriptive statistics on Interest score and Examination marks

| Variable | N | Mean | Standard Deviation | Sum | Min | Max |
|---|---|---|---|---|---|---|
| Exam | 40 | 36.18 | 7.89 | 1447 | 20 | 60 |
| Interest | 40 | 45.93 | 8.89 | 1837 | 27 | 60 |

The Pearson correlation coefficient was found to be r = 0.04043 with p = 0.8044. This means that there was no significant correlation between interest and achievement in the Physical Science examination ($p > 0.05$). This finding was corroborated by the scatter-plot of Examination vs. Interest (Figure 4.1).

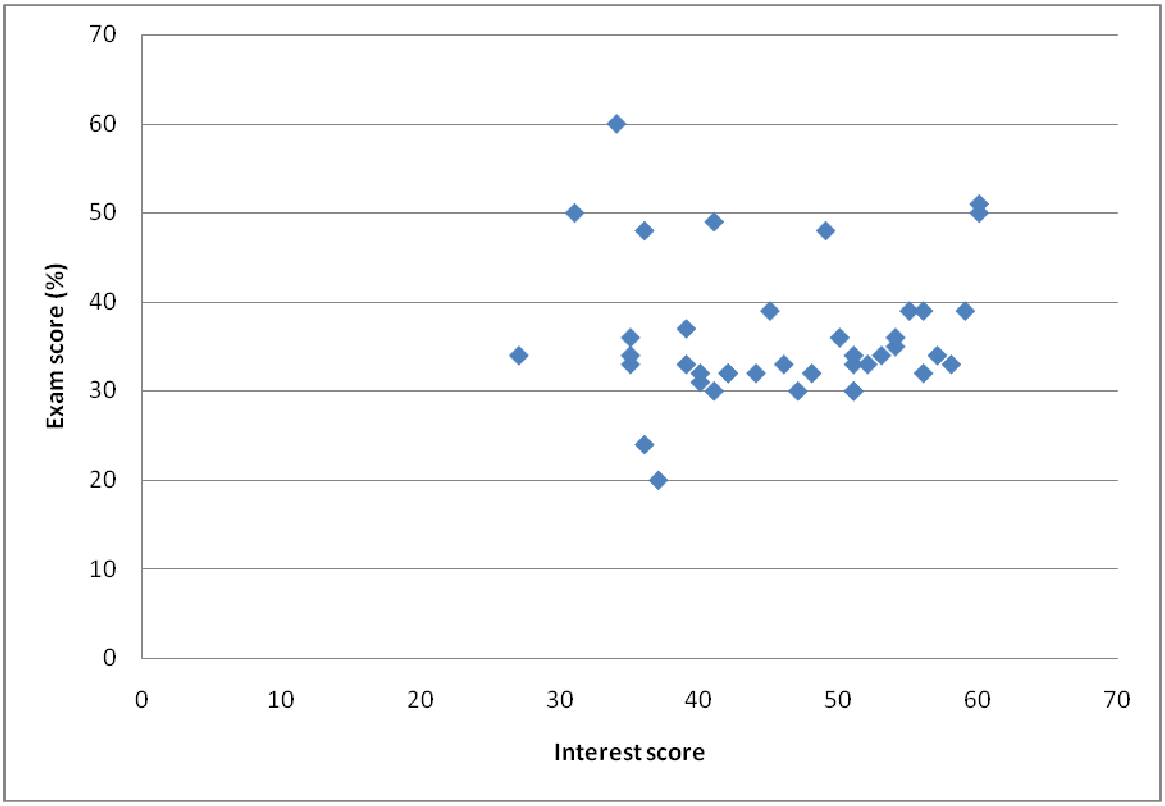



Figure 4.1 Scatter-plot of Examination score vs. Interest score

### 4.3.5 Summary of results of the interest questionnaire

The interest questionnaire was shown to be reliable. Some authors, e.g. Mulder (1986), regard a correlation coefficient of 0.4 to 0.59 as a moderate correlation and 0.6 to 0.79 as a high correlation. Tables 4.3 to 4.6 therefore indicate a very high correlation, showing that the homogeneity of each of the 4 subject interest tests is satisfactory.

There was an indication of a high preference for Computer Studies amongst grade 9 learners. It was interesting that the schools from which the learners come do not offer Computer Studies. This preference could be due to the fact that Computer Studies are linked to the world of work. According to the DoE (1997), there should be clear evidence that the Senior Phase learner is being prepared for life after school, i.e. life in the world of work, at institutions for further learning and for adult life in general. Learning programmes should create opportunities for the learner to be informed about career and further learning opportunities, about ways and means of realising his/her expectations for the future, and about his/her rights and responsibilities as a citizen in a democratic, multicultural society (DoE, 1997).

The finding that there was no significant difference between boys and girls in grade 9 with regard to interest in the so-called 'hard' subjects like Physical Science and Mathematics augers well for the future of this country. For years these subjects have been regarded as the boys' domain. However, in progressing to grade 10, it was found that interest in science increased significantly for boys but not for girls. This could be an indication that boys were coping better with the transition.

The finding of a significant difference between learners in grade 9 (GET) and the same cohort of learners in grade 10 (FET) with regard to interest shown for Physical Science ($p < 0.05$) should be treated with caution. This is a finding at the interface of GET and FET (i.e. end of grade 9 and the beginning of grade 10) and not over the overall gap as defined in the theoretical framework in Chapter 2. It still needed to be seen if this interest would be maintained throughout the FET phase. The increase in interest could be due to the learners' expectations of what Physical Science was holding for them and not due to actual experience through the FET phase.

Not surprising was the finding that there was no correlation between interest and achievement in the Physical Science examination. Interest in Physical Science may for example, be prompted by role models and job opportunities and in may not be caused by achievement or intellectual ability.

## 4.4 THE NATURE OF SCIENCE SURVEY

In this study I have adopted the Nature of Scientific Knowledge Scale (NSKS) and its subscales developed by Rubba and Anderson (1978), to explore whether learners' epistemological inclination affected their experiences of the transition.

### 4.4.1 Epistemological beliefs

The learners were classified as post-positivist-oriented or empiricist-aligned based on their score on the NOS survey. In the classification, the cut-off point was the mean score.

Table 4.13a Exam score, NSKS score and belief classification of the Physical Science group

| $V_1$ | Gender | Exam marks (%) | NSKS score | Belief group |
|---|---|---|---|---|
| 58 | F | 32 | 139 | Empiricist aligned |
| 52 | F | 32 | 140 | |
| 59 | F | 34 | 146 | |
| 54 | F | 32 | 147 | |
| 49 | F | 30 | 149 | |
| 11 | F | 20 | 150 | |
| 24 | M | 34 | 152 | |
| 47 | F | 37 | 154 | |
| 41 | M | 39 | 154 | |
| 18 | M | 50 | 154 | |
| 30 | M | 33 | 155 | |
| 17 | M | 50 | 155 | |
| 56 | F | 39 | 156 | |
| 31 | F | 33 | 157 | |
| 48 | F | 31 | 158 | |
| 35 | M | 48 | 158 | |
| 13 | F | 24 | 159 | |
| 29 | F | 34 | 159 | |
| 34 | F | 49 | 159 | |
| 33 | F | 30 | 160 | |
| 12 | F | 34 | 160 | |
| 60 | F | 36 | 160 | |
| 44 | F | 33 | 162 | Post positivist oriented |
| 25 | F | 32 | 164 | |
| 55 | M | 33 | 164 | |
| 53 | F | 30 | 165 | |
| 42 | F | 32 | 166 | |
| 45 | F | 36 | 166 | |
| 07 | M | 36 | 166 | |
| 57 | F | 30 | 167 | |
| 09 | F | 33 | 167 | |
| 21 | F | 35 | 167 | |
| 43 | F | 60 | 167 | |
| 40 | F | 34 | 169 | |
| 51 | F | 39 | 170 | |
| 50 | F | 33 | 171 | |
| 32 | M | 32 | 171 | |
| 23 | F | 39 | 173 | |
| 01 | M | 48 | 174 | |
| 28 | M | 51 | 175 | |

The post positivist-oriented learners were those that have scored above the mean and the rest are empiricist-aligned. Tables 4.13(a) shows that the classification may turn out to be an oversimplification as the NSKS scores did not vary much.

Descriptive data on the examination and NSKS scores are given in Table 4.13(b). The mean scores for boys in the examination and the NSKS are above those for the whole class, while the means for girls in the examination and the NSKS are below those for the whole class.

Table 4.13b Descriptive statistics on the examination and NSKS scores

| Variable | Group | N | Mean | Sum | Min | Max |
|---|---|---|---|---|---|---|
| Exam | Overall | 40 | 36.18 | 1447 | 20 | 60 |
| | Boys | 11 | 41.27 | 454 | 32 | 51 |
| | Girls | 29 | 34.24 | 993 | 20 | 60 |
| NSKS | Overall | 40 | 160.12 | 6405 | 139 | 175 |
| | Boys | 11 | 161.64 | 1778 | 152 | 175 |
| | Girls | 29 | 159.55 | 4627 | 139 | 173 |

Next I compared learners taking Physical Science and a group of learners not taking Physical Science. This group studied Commercial Sciences and Mathematics. Table 4.14 shows the NSKS scores of the non-Physical Science learners. Table 4.15 compares the NSKS scores between Physical Science and Commercial science groups on all the six subscales.

The following null hypothesis was tested:

- *The is no significant difference between the scores of learners who are taking Physical Science and those who are not taking Physical Science on the six NSKS subscales shown in Table 4.16.*

Table 4.14 NSKS scores of the Commercial Science group

| $V_1$ | Gender | NSKS score |
|---|---|---|
| 02 | F | 157 |
| 03 | F | 168 |
| 04 | F | 159 |
| 05 | F | 163 |
| 06 | M | 157 |
| 08 | F | 146 |
| 10 | F | 140 |
| 14 | F | 142 |
| 15 | F | 162 |
| 16 | M | 160 |
| 19 | F | 136 |
| 20 | F | 162 |
| 22 | F | 150 |
| 26 | F | 166 |
| 27 | M | 169 |
| 36 | F | 141 |
| 37 | F | 164 |
| 38 | M | 144 |
| 39 | F | 158 |
| 46 | M | 167 |

Table 4.15 Descriptive statistics on the NSKS scores of the Physical Science group and the Commercial Science group

| Subscale/Scale | Physical Science (N = 40) | | Commercial Science (N = 20) | |
|---|---|---|---|---|
| | Mean | Std Deviation | Mean | Std Deviation |
| Amoral | 23.875 | 0.4542 | 24.300 | 0.6223 |
| Creative | 29.500 | 0.7748 | 27.600 | 1.0958 |
| Developmental | 24.225 | 0.5211 | 24.500 | 0.7369 |
| Parsimonious | 23.250 | 0.4307 | 23.600 | 0.6091 |
| Testable | 29.950 | 0.4405 | 26.700 | 0.6229 |
| Unified | 29.325 | 0.6854 | 28.350 | 0.9692 |
| NSKS | 160.125 | 1.4771 | 155.250 | 2.0890 |

Table 4.16 gives the comparison of NSKS scores of the Physical Science and Commercial Science groups using the t-test.

Table 4.16 T-test Comparison of NSKS scores of the Physical Science and Commercial Science groups

| Subscale/Scale | t | P |
|---|---|---|
| Amoral | -0.54 | 0.5911 |
| Creative | 1.42 | 0.1622 |
| Developmental | -0.30 | 0.7617 |
| Parsimonious | -0.47 | 0.6407 |
| Testable | 4.26 | <0.0001 |
| Unified | 0.65 | 0.5164 |
| NSKS | 1.91 | 0.0617 |

The t-test showed that:

- *There is a significant difference between the Physical Science group and the Commercial Science group with regard to the testable subscale score ($p < 0.05$), but no significant difference between any of the other subscales.*

From Table 4.16 it was evident that there was a tendency to differ between the Physical Science group and the Commercial Science group with regard to the whole NSKS score but it is not significant. ($p = 0.0617 > 0.05$). The Physical Science group has a higher mean, but the t-test revealed that this difference was not statistically different, although the p value was close to .05.

In summary, it was concluded that learners taking Physical Science scored significantly higher on only the testable subscale of NSKS test when compared to the Commercial Science group.

Next, the NSKS scores for boys and girls taking Physical Science were compared. The following null hypothesis was tested:

- *There is no significant difference between the scores of boys taking Physical Science and those of girls taking Physical Science on all the six NSKS subscales shown in Table 4.18.*

Table 4.17 shows the descriptive statistics for boys and girls. The boys scored almost more than 2 points higher on the developmental subscale.

Table 4.17 Descriptive statistics on NSKS scores between the Physical Science boys and girls.

| Subscale/Scale | Physical Science boys (N = 11) | | Physical Science girls (N = 29) | |
|---|---|---|---|---|
| | Mean | Std Deviation | Mean | Std Deviation |
| Amoral | 24.727 | 0.8547 | 23.551 | 9.5264 |
| Creative | 28.727 | 1.2517 | 29.793 | 0.7709 |
| Developmental | 26.364 | 1.0440 | 23.414 | 0.6430 |
| Parsimonious | 22.272 | 0.8653 | 23.621 | 0.5330 |
| Testable | 29.818 | 0.9040 | 30.000 | 0.5568 |
| Unified | 29.727 | 1.3923 | 29.172 | 0.8575 |
| NSKS | 161.636 | 2.6913 | 159.551 | 1.6576 |

Table 4.18 shows the t-test comparison of NSKS scores between the Physical Science boys and girls.

Table 4.18 T-test comparison of NSKS scores of boys and girls

| Subscale/Scale | t | P |
|---|---|---|
| Amoral | 1.17 | 0.2488 |
| Creative | -0.73 | 0.4729 |
| Developmental | 2.41 | 0.0211 |
| Parsimonious | -1.33 | 0.1926 |
| Testable | -0.17 | 0.8649 |
| Unified | 0.34 | 0.7362 |
| NSKS | 0.66 | 0.5135 |

From table 4.18, it is clear that the t-test showed that the null hypotheses could be rejected only in the case of the developmental subscale, therefore it was concluded that boys scored significantly higher than girls with regard to the developmental subscale score ($p < 0.05$).

### 4.4.2 Correlation between achievement and NSKS scores

First the Physical Science group was divided into post positivist and empiricist sub-groups and their achievement in the examination compared (refer to Tables 4.13(a) and 4.19). The following null hypothesis was tested:

- *There is no significant difference between the achievement of the post positivists and empiricists.*

Next, the correlation between the NSKS scores of the entire Physical Science group (both belief groups combined) and their achievement in the 2007 grade 11 Physical Science examinations was compared. The null hypothesis was:

- *There is no correlation between the NSKS scores and achievement in the Physical Science examinations.*

Table 4.19 shows the descriptive statistics on the examination marks obtained by the two belief groups.

Table 4.19 Descriptive statistics on the examination marks of Post-positivists and Empiricists

| Variable | N | Mean | Sum | Min | Max |
|---|---|---|---|---|---|
| Post positivist | 18 | 37.0 | 666 | 30 | 60 |
| Empiricist | 22 | 35.5 | 781 | 20 | 50 |

Table 4.19 showed that the post positivist-oriented learners performed better than the empiricist-aligned learners in the Physical Science examinations. However, the difference was not statistically significant (p-value = 0.556).

The correlation between the NSKS score and examination achievement is rather weak with the Pearson correlation coefficient calculated at r = 0.25 and a p-value of 0.1188.

This finding is corroborated by the scatter-plot of Examination vs. NSKS shown in Figure 4.2.

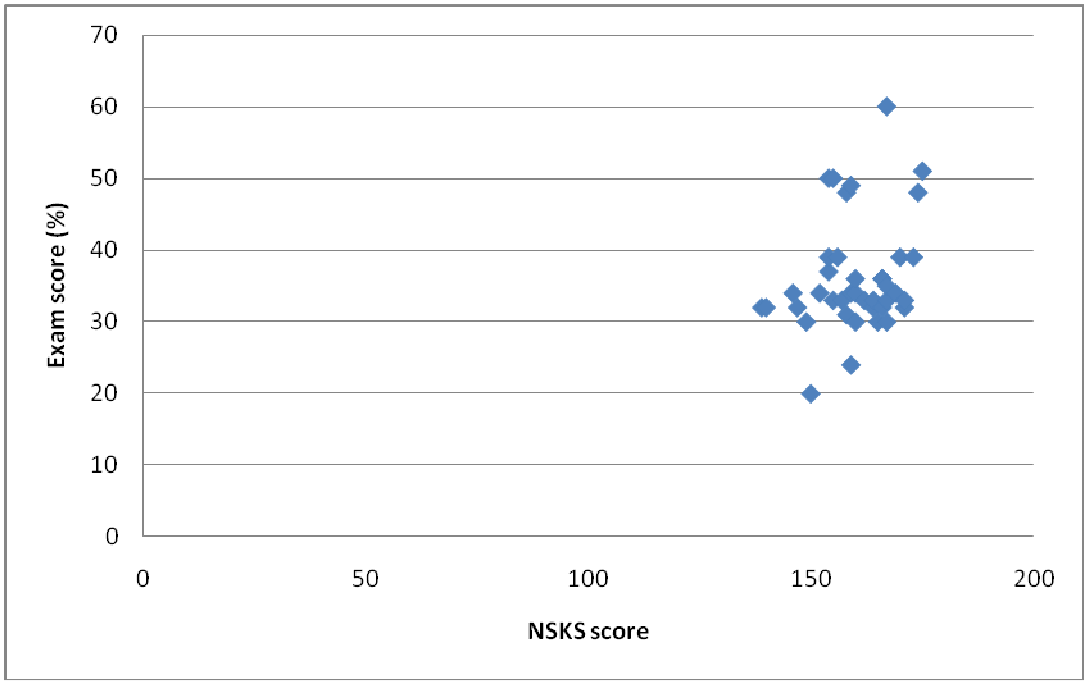



Figure 4.2 Scatter-plot of Examination score vs. NSKS score

### 4.4.3 Summary of the NOS survey results

- Learners in this study were classified as empiricist aligned or post positivist oriented. There is no significant difference between the achievement of the post positivists and empiricists in the grade 11 Physical Science examinations.
- There was no correlation between scores on the NSKS and the 2007 grade 11 Physical Science examinations.
- There was no significant difference between the NSKS scores of the Physical Science and Commercial science groups with regard to all the subscales except for the testable subscale.
- There was no significant difference between the NSKS scores of the Physical Science boys and Physical Science girls with regard to all the subscales except for the developmental subscale.

## 4.5 THE DIAGNOSTIC TEST

The results of the diagnostic test for individual student were given in Table 4.20.

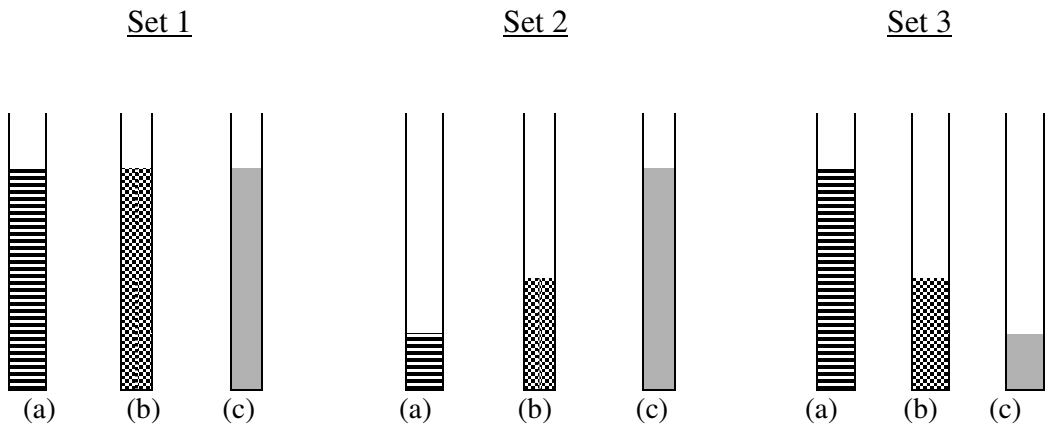
Table 4.20 Diagnostic Test: score per question with confidence levels in brackets

| $V_1$ | Gender | Age | Q1(3 marks) | Q2(3marks) | Total (6 marks) |
|---|---|---|---|---|---|
| 01 | M | 17 | 0 (100%) | 0 100%) | 0 |
| 09 | F | 17 | 0(50%) | 1(50%) | 1 |
| 11 | F | 19 | 0(50%) | 0(50%) | 0 |
| 12 | F | 17 | 0(50%) | 1(50%) | 1 |
| 13 | F | 19 | 0(50%) | 1(50%) | 1 |
| 17 | M | 17 | 0(50%) | 0(50%) | 0 |
| 18 | M | 18 | 1(50%) | 1(50%) | 2 |
| 21 | F | 17 | 0 (50%) | 0 (0%) | 0 |
| 23 | F | 17 | 1(50%) | 0 (50%) | 1 |
| 24 | M | 17 | 1(50%) | 0(50%) | 1 |
| 25 | F | 17 | 0 (0%) | 0 (0%) | 0 |
| 28 | M | 18 | 1(50%) | 0(50%) | 1 |
| 29 | F | 18 | 0(50%) | 0 (0%) | 0 |
| 30 | M | 18 | 1(50%) | 0 (0%) | 1 |
| 31 | F | 17 | 0 (0%) | 1(0%) | 1 |
| 32 | M | 17 | 0(50%) | 0(50%) | 0 |
| 33 | F | 17 | 0(50%) | 0(50%) | 0 |
| 34 | F | 17 | 1(100%) | 0 (100%) | 1 |
| 40 | F | 17 | 1 (50%) | 1(50%) | 2 |
| 41 | M | 19 | 0 (50%) | 0(50%) | 0 |
| 42 | F | 18 | 1(50%) | 0 (0%) | 1 |
| 43 | F | 17 | 2(0%) | 2(0%) | 4 |
| 44 | F | 17 | 2(50%) | 0(50%) | 2 |
| 45 | F | 17 | 0(50%) | 1(50%) | 1 |
| 47 | F | 17 | 0(50%) | 0 (0%) | 0 |
| 48 | F | 17 | 0(50%) | 0 (0%) | 0 |
| 49 | F | 18 | 0 (50%) | 1(50%) | 1 |
| 50 | F | 18 | 0 (50%) | 0 (50%) | 0 |
| 51 | F | 17 | 0 (50%) | 1(0%) | 1 |
| 52 | F | 18 | 1(50%) | 2(50%) | 3 |
| 53 | F | 17 | 0(50%) | 0(50%) | 0 |
| 54 | F | 18 | 0(50%) | 0(50%) | 0 |
| 55 | M | 17 | 0(50%) | 1(50%) | 1 |
| 56 | F | 17 | 0(50%) | 0 (100%) | 0 |
| 57 | F | 17 | 1(0%) | 1(0%) | 2 |
| 58 | F | 18 | 0(50%) | 0(50%) | 0 |
| 59 | F | 18 | 0(50%) | 1(50%) | 1 |
| 60 | F | 17 | 0 (50%) | 0 (50%) | 0 |

The table shows scores as well as the confidence levels indicated by students. Results for the two questions are discussed separately in the next two sections.

### 4.5.1 Question 1

Which of these three sets best shows 1 mole of tin, 1 mole of magnesium and 1 mole of sulphur in each tube?




(a) - tin
(b) - magnesium
(c) - sulphur

key: Set 1 - equal volumes
Set 2 - equal masses
Set 3 - equal number of atoms

Table 4.21 shows the response pattern for question 1. It also indicates the number of learners indicating a particular confidence level when giving a particular response. The number of subjects who chose set 1 (37% of all subjects) is quite large. They probably chose it because the textbook emphasizes that equal volumes of gases are a measure of equal numbers of particles, based on Avogadro's hypothesis (the subjects did not restrict Avogadro's hypothesis to gases). Only 26% of the subjects chose the right answer but none of them gave the correct explanation nor did they respond with 100% confidence. Two of them were not sure at all whether they were correct (0% confidence level)

Figure 4.3 is a diagrammatic representation of the confidence levels. It was clear from the diagram that the majority of subjects only had a 50% confidence level for each response they gave. The learners seemed to resort to rote learning when studying the mole, one of the very basic concepts in chemistry. The question may also be posed, could this be due to poor teaching?

Table 4.21 Response patterns for Question 1

| Answers | Total number of respondents | Number with 100% confidence | Number with 50% confidence | Number with 0% confidence |
|---|---|---|---|---|
| Set 1 (equal volumes) | 14 | 1 | 12 | 1 |
| Set 2 (equal mass) | 11 | 0 | 10 | 1 |
| * Set 3 (equal numbers of atoms) | 10 | 1 | 7 | 2 |
| Other [a] | 3 | 0 | 3 | 0 |
| TOTAL | 38 | 2 | 32 | 4 |

* denotes the correct response

[a] Other responses such as tin/all/none

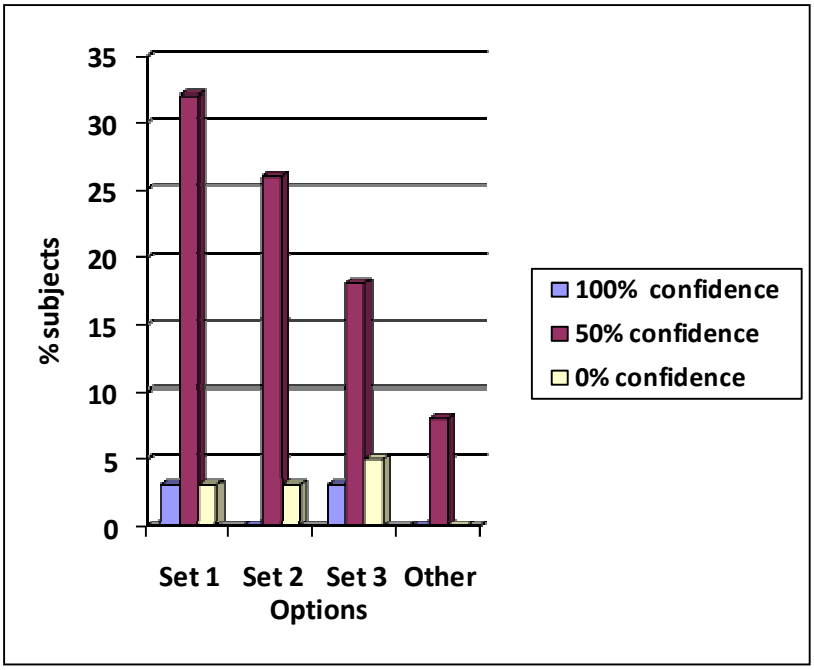
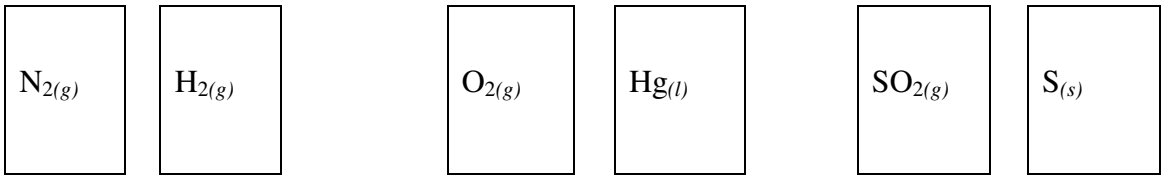



Figure 4.3 Response patterns for Question 1

### 4.5.2 Question 2

Each container represents a volume of 22,4*l* at S.T.P. In which of the three pairs of containers, if any, is there one mole in each container?




The subjects were asked to give reasons for their choice as well as for not choosing others. The response patterns are given in a Table 4.22 and a summary is given in a bar graph in Figure 4.4. A correct response would be: "The red containers contain one mole because the contents are gases at 22.4l at S.T.P. In the other pairs one of the containers has a liquid or a solid. These are much denser than the gases and therefore consist of much more than one mole of particles".

Table 4.22 Response patterns for Question 2

| Answers | Total number of respondents | Number with 100% confidence | Number with 50% confidence | Number with 0% confidence |
|---|---|---|---|---|
| *Red containers ($N_2(g)$ and $H_2(g)$) | 14 | 0 | 10 | 4 |
| Blue containers ($O_2(g)$ and $Hg(l)$) | 13 | 0 | 8 | 5 |
| Green containers ($SO_2(g)$ and $S(s)$) | 9 | 1 | 6 | 2 |
| Other [a] | 2 | 2 | 0 | 0 |
| TOTAL | 38 | 3 | 24 | 11 |

*Denotes the correct response

[a] Other responses such as none/all

Although the largest proportion (37% of all the subjects) gave the right answer, none of them provided the correct motivation nor indicated 100% confidence. The similarity in the number of atoms for each of the gas molecules in the red containers could have made it a plausible option for some subjects. Four of them were very unsure about their answers (0% confidence level). The response of those who said all containers had one mole was consistent with the misconception that Avogadro's hypothesis applied to all phases of matter.

Figure 4.4 diagrammatically illustrates the confidence levels for Question 2. It is clear from the diagram that the majority of the subjects responded with a mere 50% confidence level. That meant that they were not sure if they had the right answers.

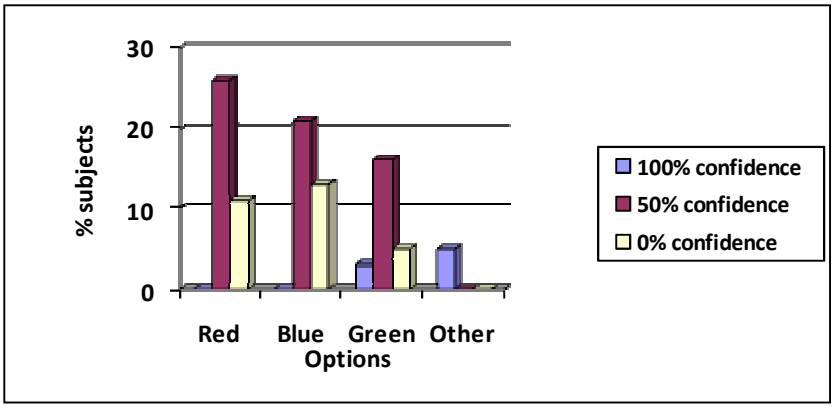



Figure 4.4 Response patterns for Question 2

Interviews with the learners would shed more light on their strategies of coping with conceptual problems. The interviews were discussed in the next chapter.

### 4.5.3 Discussion of diagnostic test results

Science education literature is replete with reports of studies relating to the identification, explanation and amelioration of students' difficulties in understanding science concepts. Such difficulties have been characterised in various ways, for example, as *misconceptions* (Fisher, 1983), *alternative frameworks* (Driver & Easley, 1978), *intuitive beliefs* (McCloskey, 1983), *spontaneous reasoning* (Viennot, 1979), *children's science* (Osborne, Bell & Gilbert, 1983) and *naive beliefs* (Caramazza, McCloskey & Green, 1981). In this study the term 'misconception' is used as defined by Cho, Kahle and Nordland (1985) to include any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus. In their description of origins of misconceptions and possible reasons for learners' lack of understanding, Garnett and Treagust (1990) identified five problem areas, namely: compartmentalization of subject knowledge; learners' interpretation of language; the use of multiple definitions and models; inadequate pre-requisite knowledge; and the rote application of concepts and algorithms.

Research on problem-solving and misconceptions in chemistry shows that chemistry is a very complex subject. Students have misconceptions and solve problems using algorithms because of the complex nature of chemistry concepts and because of the way the concepts are taught. Many of the concepts studied in chemistry are abstract and are difficult to explain without the use of analogies or models (Gabel, 1999). The diagnostic test used in the current study was based on the mole concept, one of the basic concepts in chemistry. In a survey done among teachers in the USA to determine the most difficult concepts to teach and learn, the mole was rated second only to chemical equilibrium (Aird, 1989). Perhaps it is not surprising then, to see the extremely poor results in Table 4.21 and Table 4.22.

From the responses to the diagnostic test, it would appear that:

- Learners were labouring under misconceptions or lack of knowledge of the mole.
- Learners resorted to rote application of concepts and algorithms as well as guess work when they were faced with a test in which conceptual understanding is emphasized.
- Learners were not confident about their answers.

These problems with conceptual understanding will have to be resolved in order to make transition smooth for learners moving from GET (Natural Science) to FET (Physical Science) and throughout the FET.

## 4.6 CHAPTER SUMMARY

Learners' interest in science and epistemological stance were assessed, using achievement in the examinations as a basis for comparison. Also, conceptual understanding, problem solving skills and confidence were assessed by means of a diagnostic test.

**Interest Questionnaire for the Natural Science Field of Study (IQNSFS)**

- Grade 9 boys and girls had similar interests in the four subjects and they preferred Computer Science.
- Transition from grade 9 to grade 10: Interest in Science increased significantly for boys and the overall group but not significantly for girls.
- There was no correlation between interest and achievement in the Physical Science examination.

**The Nature of Science Survey**

- There was no significant correlation between the NSKS scores and achievement in the examination. This means that a learner does not necessarily do well in the examinations because s/he has done well in the NSKS – the correspondence in the few scores between the two (examination and NSKS) can rather be ascribed to a third variable like ability or the role that memory plays or in the way in which the subjects are presented (Mulder, 1986).
- Physical Science learners scored significantly higher on the subscale 'testable' than Commercial Science learners. It seemed that they believe that scientific knowledge must be testable in order to be acceptable.
- Boys scored significantly higher on the subscale 'developmental' than girls. The boys scored higher (above the mean) in the NSKS and significantly higher in the examination. The girls scored lower (below the mean) in both the examinations and NSKS. On the basis of the significantly higher score on the developmental subscale as well as the significantly higher exam marks, the boys then tended to be high achieving post positivists and girls low achieving empiricists in general.

**Diagnostic Test**

- The test had shown a very poor conception of the mole – a basic concept in chemistry. It has also exposed rote application of concepts and algorithms. It was also clear that learners were aware of their poor understanding and poor problem solving skills, hence large degree of uncertainty about their answers.