Chapter 5: Results of the CTA investigation task

5.1 Introduction

In the previous chapter the results of the diagnostic investigation of learners' understanding of concepts of validity were discussed. In the introduction to this study, an assumption was made that there is a relationship between learners' understanding of concepts of evidence and their application in investigation tasks. In the present chapter learners' application of ideas of evidence in an investigation task will be discussed. The context (refer to Appendix F) relevant to the investigation task (adapted from the Natural Sciences Grade 9 Common Tasks for Assessment (Department of Education, 2004) was the following:

To convince their parents that they know about electricity and the investigation method, a group of children plan an investigation that they can use to show their knowledge and skills. They decide to show their parents that 'pencil lead' is a conductor of electricity which has electrical resistance. This increases with an increase in the length of the piece of pencil lead. They collect 6 new pencils. 2 of the pencils have 'hard lead' (labelled 2H), 2 'soft lead' labelled HB and 2 very 'soft lead' labelled 2B. They slit the pencils lengthwise to get the 'lead' out. They also have 2H, HB, and 2B 'pencil lead' for clutch pencils which are 0.5 mm and 0.7mm thick. They borrow two electrical meters from their neighbour who works as an electrician. The electrician sets the one meter to read current in amperes and the other to read potential difference (or voltage) in volts. They set up the circuit and record the results indicated in the table below.

	Length of the pencil in circuit (cm)	Voltmeter Volts – (V)	Current Amps – (A)	Resistance = $\frac{\text{Voltage}}{\text{Current}}$ Ohms – (Ω)
1	2.5	0.42	0.28	1.5
2	5.0	0.75	0.25	3.0
3	7.5	0.99	0.22	4.5
4	10.0	1.2	0.2	6.0

Questions

1. *Describe a variable that they should control (keep constant).* also
2. *Which variable do they change (independent variable)*
3. *Which variable is the dependent variable in their investigation?*
4. *Write down the matter they investigated?*
5. *Describe, in writing, the method they follow to answer the problem they are investigating? Include a circuit diagram.*
6. *Draw a graph of resistance against the length of the pencil lead included in the circuit. Fully label the axes and give your graph a heading.*
7. *Give the conclusion the children reach using the graph of their results. (Give the conclusion in words and mathematical symbols*).

5.2 Data Analysis

Because a performance assessment does not have an answer key in the sense that a multiple choice test does, scoring a performance assessment necessarily involves making some subjective judgements about the quality of a learner's work. Many people feel uncomfortable with making and using subjective judgements and find that a good set of scoring guidelines or "rubric" provides a way to make those judgements fair and sound. In this study, analysis of learners' responses to the questions was done using "rubrics". Frequently referred to as a scoring guide, assessment rubrics are rules with which the quality of answers is determined (Mabry, 1999). Each rubric is a description that clearly articulates a learner's performance level for each of the score points. This strategy involves reading all the responses for the class by the researcher and then sorting them into stacks according to those that have "complete" answers, those that are "missing" one or more components, and those that are unacceptable or "missed the point".

5.2.1 Selection of rubrics

There is no single best rubric for all purposes and many different rubrics can be applied to the same task. The steps for selecting rubrics are shown below:

1. *Adopt*

- Use an existing rubric "as is."

2. *Adapt*

- Modify or combine existing rubrics.
- Re-word parts of the rubric.
- Drop or change one or more scales of an analytical rubric.
- Omit criteria that are not relevant to the outcome you are measuring.
- "Mix and match" scales from different rubrics.
- Change the rubric for use at a different grade.
- Add a "no-response" category at the bottom of the scale.
- Divide a holistic rubric into several scales.

3. *Do it yourself*

- Build your own rubric from scratch.

In this study the procedure followed was: firstly, select existing rubrics which had been used for the same purpose, i.e. to score learners' responses to an investigation task. The rubrics selected were the prescribed rubric for the CTA investigation task at hand and the scoring rubric developed for open investigations by BSc Honours (Science Education) co-coordinators at the University of the Witwatersrand. Secondly, from these rubrics, re-word parts of the rubrics and omit criteria that are not relevant to the outcomes being measured. By combining the existing rubrics it became possible for the researcher to develop a more specific rubric for the task at hand. Finally, these rubrics were examined by a panel of experts or well trained scorers or science teachers to establish face validity, i.e. to confirm that the intention of the rating scales was to categorize learners' performance and that they were not open to different interpretation.

By "mixing and matching" scales from the different rubrics, the researcher managed to develop a rubric which addressed all aspects of the outcomes being measured. This was done by taking note of the following criteria for evaluating scoring rubrics taken from Mabry (1999:678).

- *Does the rubric relate to the outcome(s) being measured? Does it cover important dimensions of student performance? Do the criteria reflect current conceptions of excellence in the field? Are the dimensions or scales well-defined?*

- *Is there a clear basis for assigning scores at each scale point? Can the rubric be applied consistently by different scorers? Is the rubric developmentally appropriate? Can the rubric be applied to a variety of tasks?*
- *Is the rubric fair and free from bias?*
- *Is the rubric useful, feasible, manageable and practical?*

5.2.2 A model of analyzing and interpreting data

From the coded learners' responses to questions about the investigation task, the following performance level categories were identified:

Figure 5.1: A model for assessing learners' performance levels

1. **Exemplary: Level 4**

   The response clearly demonstrates complete understanding of important ideas and processes, provide accurate rationale, and include diagrams if needed.

2. **Competent: Level 3**

   The response generally presents a solid understanding of important ideas and processes but may have omitted one or more minor elements or ideas, or may have failed to provide a clear rationale.

3. **Satisfactory: Level 2**

   The response shows understanding of part of the question or process, but it is slightly incomplete and the rationale may be unclear.

4. **Inadequate: Level 1**

   No response or the response does not show understanding of the question; words, drawings, and diagrams are not relevant to the question or problem.

Having identified the existence of these levels in some categories, further items were written to explore the whole range within each category, and some modification was made to existing items to clarify their meaning. Following trials of this set, further adjustments were made to improve the discriminating power of each item within its category. This was done by classifying learners as at essentially level 1, 2, 3, or 4 on their performance on the total set of items within each category, and then determining the extent to which each item accurately discriminates between learners at one level and those at the next.

5.2.3 Validity and reliability

If the rubric is to meet the use prescribed for it, as a tool which can be used by any well-trained scorer to determine the quality of learners' work, it must be shown that it is *reliable*, and that it is *valid*. In this context, reliability can be demonstrated by the measure of agreement between different individuals who use the rubric to score learners' work of the set of objectives. In other words, reliability can be demonstrated by the measure of how the rubric organizes and clarifies the scoring criteria so that different raters will award similar scores. An important measure of validity will be the extent to which these rubrics made by the researcher do accurately predict the success or failure at the objectives of learners' whose performance levels have been estimated.

The questions of both reliability and validity of the rubrics were investigated. Once the researcher had decided on the levels of learners in each category, well-trained scorers or science teachers who thoroughly understand the rubric and who periodically score the same samples of learner's work were consulted to ensure that they maintain uniform scoring. Four science educators were given ten samples of learners work to score using the developed rubric. The score-agreement was ninety-nine percent. This means that the level agreement is sufficient to face-validate the rubric, and also the theory that lies behind it. Furthermore, the rubric certainly has face validity, in that it was developed directly from criteria highlighted above. The rubric therefore meets all the criteria for evaluating rubrics suggested by Mabry (1999).

5.3 Findings

Research on scientific investigations in school science suggested that one of the key points of difficulty which learners experience in carrying out/designing investigations relates to the point where they decide to identify the relevant variables (Keys, 1998). If a variable is identified as quantitative then it has to be measured, whereas if it is seen as qualitative, then values of the variable are judged or assessed using descriptive categories.

In this task, learners were asked to investigate how the length of a pencil lead affected the resistance of the pencil lead. Data are presented here for: frequencies of learners' responses on questions about the investigative problem, method description, control variables, independent variables, dependent variable, graphical skills and conclusions.

5.3.1 Control variables

The first question dealt with the control of variables necessary for a fair test. Control of variables is an essential validity concept in experimental design. As already mentioned, in some probes questions used to assess understanding of concepts of evidence, learners were asked to choose control variables and explain why these variables should be kept constant in an experiment. In this investigation task, however, learners had to describe a variable that they should control but they were not expected to justify their answers. The different levels, under which learners' responses were categorized, were:

- 1.1 no fixed variables identified for control or control variables incorrectly identified
- 1.2 shows understanding of concept of variable control
- 1.3 other variables identified and controlled or a minor but correct fixed variable identified for control
- 1.4 all possible variables identified for control

Typical learners' responses to this question about control variables were:

1.1 "Length of pencil lead" (learner 19). "The time it takes for the current to complete the circuit, but first the voltage of batteries" (learner 18). "The source of power/battery" (learner 14).

1.2 “They should use the same power supply and they must use the same pencil throughout the experiment” (learner 22). “The pencil must be the same and the current flowing through it must also be the same” (learner 25).
1.3 “The gap between the lengths or the width of the pencil lead should be the same. OR the thickness of the pencil lead” (learner 16). “They should use the same type of pencil lead” (learner 11).
1.4 “The thickness of the pencil lead and the type of the pencil lead” (learner 13). “I think they must keep the width and type of pencil lead constant” (learner 1).

The frequencies of learners’ responses to the question regarding control variables are shown in Table 5.1 below.

Table 5.1: Frequencies of learners’ responses to the question about control variables

Level	**Description of rating**	**Number of learners(n=44)**
1	• lacks of understanding of control of variables • no fixed variables identified for control • control variables incorrectly identified	**22 (50%)**
2	• shows understanding of concept of variable control	**10(23 %)**
3	• other variables identified and controlled • a minor but correct fixed variable identified for control	**9(20%)**
4	• all possible variables identified for control	**3(7%)**

As can be seen from Table 5.1, only 3 out 44 (7%) were successful in identifying the most control variables in this investigation, viz. the thickness of the pencil lead and the type or hardness of the pencil lead. 9 out of 44 (20%) of the respondents managed to state that the pencil and its leads should be kept constant. However, it is not clear whether these learners were referring to the thickness, type or the length of the pencil lead.

Twenty three percent (23%) of the responses fell into level 2. These respondents seemed to have an understanding of the concept of control variables, even though they identified a minor but correct fixed variable for control. Moreover, almost half of the learners' responses (50%) show lack of understanding of the control variables by the learners. In other words, these learners were not able to identify the control variables in this investigation at all. Most of them seemed to answer the question with only a rudimentary idea of what they were doing, with virtually no understanding of the concepts used in the question. However, close scrutiny of learners' responses, to a later question regarding method followed to answer the investigative problem (5.3.4), revealed that the large majority of learners did design a logical system for organizing the testing of multiple variables. An analysis of the learners' written investigation method/procedure indicated both understandings of the need to control variables and a desire to manipulate one variable in an experiment. 27 out of the total 44, or 61% of the investigation methods described experiments that included the control of variables. These investigation methods demonstrated an attempt to control variables (type and thickness of pencil lead) and manipulate only one variable in an experiment (length of the pencil). It is also interesting to note that of those 27 learners who demonstrated an attempt to control variables in their investigation plans/methods, 15 of them are among the 22 learners who failed to describe the control variables in question 1 (describe the variable that they should keep constant). Thus there is evidence that these learners have an understanding of the concept of variable control. However, the relative failure of learners to apply the concept of 'control variable' must be a cause for concern. Why is performance so low? Two fundamental questions must be raised:

- Are the majority of learners unable to understand (and therefore apply the concept)?
- Is the question not tapping learners' knowledge and, therefore, underestimating their understanding?

One possible explanation of the apparent lack of learners' achievement in the question could be that these learners did not seem to have understood the question. The other possibility is that traditional forms of assessment fail to uncover the knowledge learners have acquired. A consequence of the first view – that many learners were puzzled by the question – is that assessors have to use a variety of question modes, i.e. short and long written questions and short and long practical tasks. If the underachievement was a consequence of the method of assessment, we should therefore look to a broadening of techniques/methods for investigating learners' understanding (and therefore application) of concepts of evidence

5.3.2 Independent and dependent variable

Questions 2 and 3 dealt with what is to be changed (the independent variable) and what is to be measured (dependent variable).Learners' responses to the questions about the dependent and independent variables were categorized as follows:

2.1 Independent or dependent variables not correctly identified

2.2 Some variables identified or correctly identifies one possible independent or dependent variable

2.3 Correctly identifies dependent or independent variables but incorrectly described or worded

2.4 Correctly identifies all possible independent or dependent variables

Typical learners' responses to the questions on dependent and independent variables were:

2.1 "Voltage of the battery" (learner 28 – independent variable). "The current flowing through the lead" (learner 32 – independent variable). "Ammeter (current) and voltmeter (voltage)" (learner 34 – dependant variable). "Voltmeter" (learner 9- dependent variable).

2.2 "Pencil lead" (learner 30 and 14 – independent variable). "length" (learner 11 – independent variable). "The type of pencil lead" (learner 21-dependent variable). "The pencil lead and electrical resistance through it" (learner 37-dependent variable).

2.3 "Pencil length" (learner 33-independent variable). "The change in the length of the pencil" (learner 38 –independent variable). "To show that electrical resistance depends on length of pencil lead" (learner 30 –dependent variable). "Electrical resistance" (learner 19 –dependent variable).

2.4 "The length of the pencil lead connected in the circuit" (learner 44 – independent variable). "They should change the length of the pencil lead in order to see how it will affect the resistance" (learner 41-independent variable). "The resistance of the pencil lead" (learner 10 – dependent variable). "The electrical resistance in a pencil lead, which depends on the length of the pencil lead" (learner 14 – dependent variable).

The frequencies of learners' responses to the questions about the dependent and independent variables are shown in Table 5.2 and Table 5.3.

Table 5.2: Frequencies of learners' responses on choice of independent variable

Level	**Description of rating**	**Number of learners(n=44)**
1	• independent variables not correctly identified	**4 (9%)**
2	• correctly identifies one possible independent variable	**6(14%)**
3	• correctly identifies up to 2 possible variables	**3(7%)**
4	• correctly identifies all possible independent variables	**31(70%)**

Table 5.3: Frequencies of learners' responses on choice of dependent variable

Level	**Description of rating**	**Number of learners(n=44)**
1	• dependent variables not correctly identified	**5(11%)**
2	• some variables identified	**6(14%)**
3	• correctly identifies dependent variable but incorrectly described or worded	**3(7%)**
4	• correctly identifies dependent variables	**30(68%)**

As can be seen from Table 5.2, the large majority of learners responses (3 plus 31) fell into the highest levels (levels 3 and 4). This implies that the large majority of learners (34 out of 44, or 77%) were successful at identifying the independent variables (the length of the piece of pencil, potential difference across the pencil lead and the current through the pencil lead). However, only 3 out of these 34 learners could not word or describe one of the variables correctly. Furthermore, very few learners (4 out of the total 44, or 9%) incorrectly identified the independent variables. 6 out of 44, or 14% of the learners identified only one variable of a particular type. Learners were similarly successful at identifying the dependent variable. The findings appear in Table 5.3 above. 33 out of 44, or 75% of the learners' responses fell into the highest levels (levels 3 and 4). Thus 77% of the learners were able to identify the dependent variable (resistance) correctly. Similar to the findings in Table 5.2, very few learners (5 out of 44, or 11%) incorrectly identified the dependent variable.

5.3.3 Investigative problem

Question 4 required learners to identify the problem under investigation from the procedures used.

The learners' responses to the question about the investigative problem were categorized according to the following levels:

- 3.1 Problem poorly stated or not stated
- 3.2 Problem stated but variables not clearly defined
- 3.3 Problem coherently stated in terms of variables to be investigated
- 3.4 Problem is well formulated as a question and shows awareness of significance of variables

Typical learners' responses for each level were:

3.1 "To prove that a pencil lead is a conductor of electricity and has electrical resistance" (learner 31). "Pencil lead as a conductor of electricity" (learner 41).

3.2 “The increase of resistance to the length of the pencil leads” (learner 18). “To investigate the electrical resistance of a pencil lead by means of the length of the pencil lead” (learner 40).

3.3 “The effect of the length of the pencil lead on the resistance of the pencil lead” (learner 38). “To investigate the change in resistance of the pencil due to the change in length of the pencil lead” (learner 37).

3.4 “What is the relationship between the length of the pencil lead and its resistance?” (learner 18). “How does the length of the pencil lead affect the resistance of the pencil lead?” (learner 1).

The frequencies of learners’ responses to the question about the investigative problem are shown in Table 5.4 below.

Table 5.4: Frequencies of learners’ responses to the question about problem investigated

Level	**Description of rating**	**Number of learners(n=44)**
1	• problem poorly stated or not stated	**4(9%)**
2	• problem stated but variables not clearly defined	**4(9%)**
3	• problem coherently stated in terms of variables to be investigated	**8(18%)**
4	• meets level 3 criteria and in addition: • is well formulated as a question • shows awareness of significance of variables	**28 (64%)**

As can be seen from Table 5.4 above, the majority of learners (about 82%) stated clearly and coherently the problem investigated. The most common level was level 4, in which the learners were able to formulate the investigative question satisfactorily, showing the awareness of significance of variables. This means that these learners could formulate the problem as a question in terms of the variables investigated. The questions that the learners generated can lead to what science educators/researchers would recognize as descriptive, implying cause-effect relationships. In other words, these learners generated experimental questions that explored the effect of one variable (length of pencil lead) on another variable (resistance of pencil lead) on a scientific phenomenon. Very few learners actually failed to state the problem investigated. 18 % of learners' responses were either at level 1 and 2 (Table 5.4).

5.3.4 Method description

Question 5 focused on procedures for ensuring valid measurements, starting from a description of an investigation which indicates what variables are to be controlled, changed and measured.

The frequencies of learners' responses to the question about the method followed to answer the investigative problem are shown in Table 5.5 below.

Table 5.5: Frequencies of learners' responses on method description

Level	**Description of rating**	**Number of learners(n=44)**
1	• Method/design poor or absent	**3 (7%)**
2	• Method/design inappropriate for problem formulated • No indication of dependent variables, independent variable and variables needed for control. • No mention of measuring variables.	**4(9%)**
3	• method/design appropriate for problem formulated • Learners also identify independent variable, dependent variable and all the variables needed for control.	**10(23%)**
4	• Meets level 3 and in addition • They also indicate how they will measure variables.	**27(61%)**

Inspection of Table 5.5 above indicates that the large majority of learners' responses fell into the highest levels (levels 3 and 4) .The most common level was level 4, in which the learners prescribed the procedure with apparatus, variables to be manipulated and controlled, and how to measure variables. Twenty seven or 61% of the learners' responses fell into this level. This means that these learners came up with a systematic method for manipulating and controlling variables. Their designs also indicated how they would measure variables. Their report designs/plans included the following:

Steps followed to carry out the investigation:

1. *Vary the length of pencil lead*
2. *Ensure the type and thickness of the pencil is always the same*
3. *Measure the current flowing through the pencil and the potential difference using meters, i.e. voltmeter records/measures potential difference and ammeter records/measures current.*
4. *Determine the ratio of voltage to current to find the resistance.*

Moreover, 10 out of 44, or 23% of the respondents prescribed a method appropriate for the problem formulated, but made a minor error. Thus the findings suggest that most learners (37 out of the total 44, or 84%) were successful at describing the method to answer the question investigated. Their investigation methods demonstrated an attempt to control variables (type and thickness of pencil lead) and manipulate only one variable in an experiment (length of the pencil). Eventually, their investigation designs included procedures for varying the length of the pencil lead, and the procedure for measuring variables. However, very few learners (7 out 44, or 14%), designed poor or inappropriate method for the problem investigated. In other words, these learners could not come up with a logical method to answer the investigative problem.

5.3.5 Interpretation of data

In science and in science education, information is frequently presented in the form of graphs, tables and charts. Some of the questions in the investigation task were intended to test learners' abilities to read and express information or to transfer it from one form to another. The choice of a graph type of data processing in cases where the relationship between variables is investigated (in this investigation the resistance and length of pencil lead were the most often chosen variables) is limited to a straight line graph. The use of a straight line graph makes the relationship clearly visible. Interpretation and a more precise relationship between variables are also made easier.

5.3.5.1 Graphical skills

A summary of results on graphical skills is given in Table 5.6 below.

Table 5.6: Frequencies of learners' responses to 'straight line graph'.

Level	Description of rating	Number of learners(n=44)
1	• non linear or inappropriate scales used on graphs • many errors on construction of graph • uses "dot to dot" technique to draw graph • no graph	**1(1%)**
2	• straight line forced on non linear data • graphs have linear scale but some details not correct on graph • superficial explanation of data trends	**3(7%)**
3	• graphs drawn have sensible scales and points used to draw line of best fit • all details such as units and labels correct on graph • appropriately identifies data trends	**40 (92%)**
4	• meets level 3 and in addition • takes account of spread of data	**-**

Because of the way the task was structured it was not possible to have learners in level 4. In fact the task itself did not allow learners to demonstrate their knowledge and understanding of spread of data, so level 3 was the highest level as far as the task was structured. From Table 5.6 above, it appears that the vast majority of learners' responses (40 out of 44, or 92%) fell into the highest level (levels 3). This implies that 92% of the learners can draw graphs with sensible scales, taking into account details such as units and labels as well as data trends. The breakdown of these responses is presented in Table 5.6.1 below.

Table 5.6.1 Breakdown of learners' responses to 'straight line graph'

Component of responses	Percentage of learners answering each component correctly
a) Y axis equal interval scale	92
• Sensible choice of scale	92
• Correctly labelled (resistance)	92
• Correct unit (ohms)	92
b) X axis equal interval scale	92
• Sensible choice of scale	92
• Correctly labelled (length of pencil)	92
• Correct unit (cm)	92
c) All points plotted correctly and draws straight line graph	60
• Appropriate heading	80

Although research indicates that a task that comprises of a sequence of different steps obviously presents a large number of opportunities for failure, many learners in this study successfully completed the whole task. As can be seen from Table 5.6.1 above, 92% of the respondents correctly drew a graph with sensible choice of scale, equal interval scale of axis and correct units and labels. Moreover, sixty percent of the respondents successfully completed the whole task. Thus, the findings suggest that most learners were able to complete the various components of drawing a graph with no difficulties.

5.3.5.2 Drawing conclusions from data.

Question 7 focused on using results to decide the issue under investigation. This is done by answering the question investigated and by using the results obtained from an investigation. Interpretation of results was categorized according to how learners stated the conclusions they drew from the investigation.

The learners' responses to the question about the conclusions to be drawn from data were categorized according to the following levels:

- 4.1 No conclusions, or conclusions not related to data or question asked
- 4.2 Some simple correct conclusions drawn but not critically described.
- 4.3 Correct and insightful conclusions are drawn from data, *Relationship in words.*
- 4. 4 Meet level 3 criteria and state a relationship in symbols (R pencil lead α length of pencil lead), i.e. *Relationship in words plus conditions*.

Typical learners' responses to the question about the conclusions to be drawn from data were:

4.1 "My conclusion is that the ammeter is reading the current and that when the voltage increases the current decreases and the resistance is determined by dividing the voltage by the current" (learner 41). "The relationship between the two is balance because it is a straight line and the graph is Rα L" (learner 30).

4.2 "The greater the length of the 'pencil lead', the greater the resistance of the pencil lead" (learner 15). "The resistance increases with an increase in length of the pencil lead" (learner 26).

4.3 "Resistance of the 'pencil lead' is directly proportional to the length of the pencil lead" (learner 38). "The graph shows a direct proportion because when the length of the pencil lead increases the resistance also increases" (leaner 8).

4.4 "The graph shows that when the length of the pencil lead is increased, the resistance also increases if the same type of pencil lead is used, which means that the resistance is directly proportional to the length or Rα L" (learner 14). "Resistance of the 'pencil lead' is directly proportional to the length of the pencil provided the thickness, the type and the temperature are kept constant, i.e. resistance(R in Ω) α length of pencil lead (L in cm)" (learner 31).

The frequencies of learners' responses, at each level, on drawing conclusions from data are presented in Table 5.7 below.

Table 5.7: Frequencies of learners' responses on drawing conclusions from data

Level	Description of rating	Number of learners(n=44)
1	• No conclusions, or conclusions not related to data or question asked	**2(5%)**
2	• Some simple correct conclusions drawn but not critically described	**3(7%)**
2	• Correct and insightful conclusions are drawn from data. *Relationship in words*	**5(11%)**
4	• Meet level 3 criteria and in addition: • Relationship in words plus conditions. • State a relationship in symbols (R pencil lead α length of pencil lead)	**34 (77%)**

As can be seen from Table 5.7 above, only 2 out of 44, or 5% of the respondents experienced difficulty in drawing correct conclusions from data. 3 out of 44, or 7% of the respondents drew some simple correct conclusions, but could not critically describe their conclusions. However, the vast majority of learners' responses fell into the highest level (level 4). 34 out of 44, or 77% of the learners fall into this level. This means that most learners drew a conclusion in the form of a trend (reflecting a relationship, in words and symbols plus conditions). A further 11% of the respondents drew correct and insightful conclusions from data, but could not state clearly the conditions. The data suggests that many learners in our sample have an understanding of continuous data. In other words, these learners can clearly and critically draw/describe continuous data.

5.4 Conclusion

This chapter has presented the results of learners' ability to apply concepts of evidence to the CTA investigation task. In brief, the main findings in this chapter are:

- The majority of the learners showed their ability to apply their understanding of concepts of evidence to the CTA investigation task.

- The results showed that the understanding of identifying variables, designing investigations, constructing graphs and drawing conclusions form data were the most applied concepts of validity whilst the understanding of controlling variables was the least applied concept of validity. Notwithstanding this, majority of the learners included in their plans or method anything suggesting that appropriate variables would be controlled in order to make sure that the one identified to be changed was understood as the only variable to be changed. The implication is that the majority of these pupils showed their ability to apply concepts of evidence. They can read straightforward information from graphs, tables, draw accurate graphs, and interpret results. This suggests that learners were able to deal with investigations of the effect of a variable which could take a range of values. Indeed these learners demonstrated that they have the necessary knowledge for designing a fair experiment. They showed that they can prescribe an appropriate investigative question and method to answer this problem and interpret data. Therefore if presented with an assessment task to apply concepts of evidence in experimental design, the majority of learners have shown that they can be able to demonstrate their understanding of concepts of evidence and that they can be able to translate the problem into a relevant practical activity. And also that they would be able to set up the conditions necessary to provide a solution.

The next chapter elaborates on the findings stated in chapter 4 and 5 by way of discussion, conclusion and recommendations.