CHAPTER SIX: SYNTHESIS

6.1 INTRODUCTION

This is the concluding chapter of a four-year longitudinal study into learners' experiences of transition from the Natural Sciences in the GET phase to Physical Science in the FET phase at a time of curriculum change. The learners who participated in the study were a unique cohort. They were the first group who started schooling under C2005. Throughout the GET phase they had been following the outcomes-based C2005. They were also the last group of learners to complete their compulsory schooling under that curriculum in 2005 because the curriculum was revised and content was re-introduced in the NCS when they started grade 10 in the FET phase in 2006. They were also the first group to complete the NCS in grade 12. The progress and experiences of this group from the GET band to the FET band should therefore have generated much interest from both the political and educational perspectives.

In this chapter, conclusions were drawn from the results to answer the research questions. Difficulties experienced during transition were discussed in detail. Reflecting on the study, I made the case that the gap encountered at the articulation of the transition perpetuated throughout the progression during the FET phase, ultimately leading to negative experiences and poor coping. Having highlighted the limitations and given directions for further study, I made recommendations for the appropriate sectors of education.

6.2 TRIANGULATION OF RESULTS

The study implemented a mixed methods approach, using various instruments. The previous two chapters provided a comprehensive analysis of the quantitative and qualitative data collected. A clear picture emerged by combining the results from the various sources. Triangulation of results, represented in Table 6.1 indicated that the different data sources yielded converging results. These results could therefore be regarded as trustworthy in the context of this case study.

Table 6.1 Triangulation of results

Research question	Results	Data source
(i) How can the transition from Natural Science in GET to Physical Science in the FET be characterized?	Less emphasis of experiments in FET	**Classroom observation**
	Content mismatch in science curriculum between GET and FET.	**Documentation**
	Huge difference in assessment practices.	
(ii) 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?	Interest in science increases at the interface between the GET and FET and then declines throughout the FET	**Interest questionnaire**
	Boys show a larger increase in interest in Physical Science than girls from grade 9 to grade 10	**Interview**
	Teacher-student relationship has drifted apart	
	Teacher-dominated lessons and teaching strategies do not meet expectations.	
	Lack of conceptual understanding,	**Diagnostic test**
	Boys do better on the NOS developmental subscale than girls and in the grade 11 exam	**Grade 11 exam**
	Physical Science learners scored significantly higher on the NOS subscale 'testable' than the non-Physical Science learners. They are also frustrated by lack of experiments	**NOS Questionnaire**
(iii) How can the learners' strategies and approaches for negotiating the transition be understood and explained?	Learners resort to cramming, reading (not doing) experiments, rote application of concepts and algorithms.	
	Career choice: mostly not in the Physical Sciences	
	Tendency towards post positivism provides better coping skills for examinations	

6.3 RESEARCH QUESTIONS REVISITED

6.3.1 Characterization of the transition

The first research question of the study was:

How can the transition from Natural Science in GET to Physical science in the FET be characterized?

Document analysis, classroom observations and interviews indicated that the transition was characterized by a discontinuity of the curriculum from outcomes based to content based teaching, inadequate pre-requisite knowledge for FET Physical Science, dissimilar assessment practices, different teaching strategies and less emphasis on practical work in the FET phase.

Analysis of documents confirmed that the discontinuity of the curriculum created a gap at the interface between the GET and FET bands. Learners in this study followed Curriculum 2005 when they were in grade 9, the curriculum in which content was left to the discretion of the teacher and the school. Those who graduated to grade 10 in 2006 were faced with a curriculum in which the assessment standards specified content to be taught. The grade 10 Physical Science teacher was faced with the daunting task of determining which aspects had been covered by the learners in grade 9 Natural Science and which had not been covered. As seen from document analysis, the aspects covered in grade 9 Natural Science Common Tasks for Assessment (CTA) were by no means testing knowledge required for grade 10 Physical Science. Further analysis of documentation showed that assessment methods for grade 9 and grade 10 differ markedly. In grade 9, 75% of the final mark was based on continuous assessment (CASS) and 25% on summative assessment. In grade 10 it is the other way round, with 25% of the final mark from CASS and 75% from the summative assessment at the end of the year. I contend that this contributed to the large repetition rate in grade 10.

Classroom observations were conducted in 2006 when the subjects were in grade 10. The teacher still used the old method of teacher-centred approach, even in cases which lent themselves to learner-centred activities. Rogan (2004), in his study of the implementation of

Curriculum 2005, also reported that the largest percentage of instructional time was spent on lecturing in most science classrooms. What concerns me more is his finding that in the practical domain there was 'room for lots of improvement' (p.174). In my study, in lessons 7 and 8, the teacher could have easily allowed the learners to practically observe the characteristics of metals with a simple, easily obtainable example of copper wire, bulb and a battery: solid, shining, malleable, conductor of heat and conductor of electricity. However, the teacher confined himself to short-term objectives of the lesson, largely ignoring assessment standards. His teaching method did not lend itself to imparting skills, such as critical thinking and problem-solving, drawing conclusions, identifying and controlling variables, evaluating conclusions, hypothesizing, measuring, predicting, observing and comparing. Furthermore, interviews revealed that learners were not exposed to practical work in the FET phase, as confirmed by classroom observation, with the teacher turning a practical lesson into a theoretical lesson. The gap between the teaching strategies in the GET and FET therefore extended throughout the progression through the FET due to teacher centred lessons and lack of practical work throughout the FET phase.

6.3.2 Learners' experiences of the transition

The second research question was:

How did 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?

The interest questionnaire, grade 11 examination scores, diagnostic test and interviews revealed declining interest in Physical Science, disappointment in relationships with teachers and teaching strategies, poor conceptual understanding and poor performance throughout the progression of the FET phase.

Generally, interest in science increased at the interface between the GET and FET and then it declined throughout the FET band. The initial increase in interest was shown to be significant for boys. Learners experienced the teacher-student relationship as distant in the FET band compared to the close relationship in the GET band. From interviews and classroom observation it was concluded that lack of experiments in FET did not meet their expectations regarding teaching strategies. Poor conceptual understanding was revealed by the diagnostic test, interviews and the poor average results in the grade 11 examination. I therefore argue that learners faced with these challenges would find it difficult to make a smooth transition from Natural Science to Physical Science. The majority of learners expressed the view that the transition was not smooth, rather that it was difficult. Using the cross-border metaphor, one can describe this transition as hazardous (Cobern & Aikenhead, 1998).

Interest in Science

In grade 9, boys and girls showed similar interest in Physical Science. In grade 10, learners' interest in science was found to increase at the articulation of the two phases (end of the GET phase to beginning of the FET phase). This emerged from the statistical analysis of the descriptive data from the interest questionnaire (IQNSFS) that was conducted towards the end of 2005 and again in the first half of 2006. The change in interest as learners moved from grade 9 to grade 10 was significant in the case of boys but not for girls. The increased interest in Physical Science amongst boys may be related to their tendency towards post-positivism. This tendency towards post-positivism was revealed by boys' significantly better performance on the developmental scale of the NOS questionnaire, discussed in the next section.

Positive attitudes towards science declined for most learners during the progression through the FET phase. For example, Hazel Planck remarked:

> *My interest in science is declining because in the FET phase it's more complicated. I think the work is more and you have to memorise all these terms.*

Three boys were the only ones to indicate increased interest during the progression. For example, Humphrey Edwards said:

> *I think it is increasing because from grade 10 to grade 12 we were introduced into new things like for instance momentum and the rates of reactions … you get to know how something happened that I did not understand how they occurred … but now through science I understand why is it that all things go down and not up … so I think being introduced to new things … things that are related to everyday life … I think it is increasing.*

The interviews were conducted when the learners were in their final year of the FET phase and were asked to reflect on the whole period from the GET to the FET. The result is in agreement with various studies in Australia that concluded that students' interest in and enjoyment of science decline sharply during the secondary school years (Baird, 1994). It appears that learners prefer the subjects in which they do well and will lose interest in those in which they perform poorly, as is the case with Physical Science in the FET phase. In the current study, learners indeed performed poorly as demonstrated by the grade 11 examination results. Of course, a lack of interest would also contribute to poor performance. The relationship between interest and performance therefore worked both ways creating a downward spiral of poor performance and lack of interest.

Most of the learners did not indicate Physical Science as their favourite subject. Reflecting on the interest questionnaire I found that there was no correlation between interest and achievement. It is therefore not surprising that high achievers in Physical Science had other subjects as their favourites. For example, the favourite subject for Hazel Planck was Mathematics:

> *My favourite subject is Mathematics because in Mathematics we do more with figures … and you have to calculate … it's not all about cramming the notes you are given … you have to know your subject and you have to practice.*

Learners' decreasing interest in Physical Science was related to the lack of practical work in the FET phase, as discussed below.

Disappointment with teaching strategies

The interviews showed that the teaching strategies in Physical Science did not meet the learners' expectations. It is my view that this disappointment contributed to the decrease of interest throughout the progression of the FET band. On the question of their expectations of teaching strategies in the FET band, the majority of learners expressed disappointment at the lack of opportunities to do experiments in the FET phase, particularly chemistry experiments in Physical Science. When asked if the teaching strategies in Physical Science met their expectations, typical responses were:

Hazel Planck: *No, it is not, because when I was in grade 8 and 9 we did a lot of experiments … science was more of a practical subject but as we get to grade 10 we get stories like a … things that we have to do like experiments … they are expensive and we can no longer do them …so science is now more like …you have to cram and … know terms by heart without actually seeing the things you are talking about.*

Henry Els: *When you have to do certain parts, especially in chemistry … that's where you have to do experiments .. so you find out that the school does not have enough material to help us out .. so you end up doing the experiment as part of theory.*

Howard Prins: ……. *most of the time we only do theory and we don't normally use the labs, especially in chemistry for practical so you can understand more if you do practical but when you only do theory sometimes it's hard to understand.*

The quotes above both confirmed that the learners found it hard to understand the FET science and that they ascribed their poor understanding to the lack of practical work. This is not surprising against the background of the mismatch of the GET and FET curricula. GET science is typically hands-on and is aimed at giving practice in problem-solving skills (Rennie, 1984; DoE, 2002(b)) and learners graduating from GET phase to FET phase were justifiably expecting the continuation of these hands-on activities. The learners expressed their disappointment at the lack of activities as well as listening to lectures, similar to results found by Baird (1994).

Learners' frustration over not having the opportunity to do experiments could be related to their understanding of the Nature of Science. There was a tendency to differ between the Physical Science group and the Commercial Science group with regard to the whole NSKS score and the difference between the groups was significant on the subscale 'testable' where the Physical Science group scored much higher. This could explain why the science learners were frustrated by the lack of experiments, because they generally believed that the validity of scientific knowledge was established through repeated testing against accepted observations. I propose that the exposure of Physical Science learners to Learning Outcome 1 on Scientific Investigations (DoE, 2002(b)) contributed to their understanding of the testable aspect of the Nature of Science, leading to their expectations to do experiments, and their disappointment at the lack of opportunity to actually do experimental work.

Disappointment with student-teacher relationships

On the question of teacher-student relationships, the majority of learners lamented the loss of a closer relationship with their Natural Science teachers in the GET phase as exemplified in the following responses:

> Humphrey Edwards: *I think from grade 10 downwards, the relationship was kind of a parent and child ... because we were not ... they still took us as children .. . like they had to guide us … talk to us … understand us but since from grade 10 to grade 12 sometimes we were taught by an HOD … he's got a lot of duties so actually he just comes to teach you … you only have time to talk in class because they teach different classes and some are deputy principals they have to do some things … so it's kind of a distant relationship*

> Henry Els: *It's different … because …from the early grades .. teachers try to make us have more love for science rather than the ones we have right now. In the FET section, they come to class, teach you and the other work is for you to do*

The disappointment was understandable, considering the fact that these learners experienced the caring culture of GET schooling and now found themselves in a more academically fragmented and competitive climate of FET schooling (Eyers, 1992).

Conceptual understanding and performance

The poor examination results in grade 11 as well as the poor performance in the diagnostic test revealed poor conceptual understanding. During interviews, the learners reported that they did not understand many of the new concepts. They blamed their lack of understanding solely on the lack of experimental work in class. They resorted to reading the experiments from the textbook, memorizing terms and rote application of concepts and algorithms when solving problems. Even the best performing student in science admitted to poor understanding, which she related to a lack of practical work:

> Hazel Planck: *My interest in science is declining because in the FET phase it's more complicated. I think the work is more and you have to memorise all these terms. It's more work and the chemistry part … I like the chemistry part as I was doing grade 9*

and grade 8 but as I got to grade 10 it was more difficult because there was a bit of change in the way it was taught and the way I understood it; and the other thing is that we don't have laboratory so we have to read the experiment from the text-book and cram it.

The poor performance and low confidence revealed by the diagnostic tests suggested poor conceptual understanding. The responses to the interviews following up on the diagnostic test confirmed that learners had a very poor understanding of a basic chemistry concepts like the mole and that they held misconceptions about Avogadro's law. When asked why he said all containers had one mole of each substance, Herman Pattington replied as follows:

I said all containers contain one mole … because when you use the formula $n = V/V_m$*, I get one mole for all the containers … since the volume of the containers is the same and the constant molar volume is the same, so I arrived at the same conclusion for all the containers.*

This is consistent with the misconception that Avogadro's hypothesis applies to all phases of matter. In general, I found learners' problem-solving strategies during transition to be rote application of concepts and algorithms and guesswork, a serious indictment on both the teaching strategy of the teacher and the learning style of the learners.

Misconceptions and lack of understanding can be related to various factors, including inadequate pre-requisite knowledge and the rote application of concepts and algorithms (Garnett & Treagust, 1990). In the current study the role of inadequate pre-requisite knowledge was a factor contributing to learners' difficulties in conceptual understanding, with this leading to rote learning and algorithmic problem solving as a coping mechanism.

6.3.3 Learners' strategies and approaches to negotiating the transition

The third research question was:

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

The diagnostic test and interviews revealed that in general, learners resorted to cramming, rote application of algorithms and to avoiding career choices involving Physical Science. Also, the interest questionnaire and examination scores indicated that boys generally coped better than girls in negotiating the transition. The NOS survey indicated that boys were inclined towards post-positivism as they scored significantly better on the developmental subscale. This could explain boys' better coping, as measured by better performance in the examinations.

Rote learning and algorithmic problem solving

The diagnostic test assessed understanding of one of the basic concepts of chemistry, namely the mole. The test was also designed to reveal learners' problem solving strategies when faced with assessment that emphasized conceptual understanding. The test revealed algorithmic problem solving and rote learning. During interviews learners admitted that they used rote learning ('cramming').

The term rote learning has often been used to describe the study methods of learners. Learners are seen to memorize large portions of the textbook and then to reproduce this information in a test. Very often these learners have little real understanding of the study material. They look for key words in the question and then dump all the information that they think is relevant to the question. They rarely relate the information to the particular demands of the question (Van der Vyver, 2000). This was indeed the case with subjects in the current study.

Epistemological belief seemed to have an influence on coping with the transition because boys, who had a tendency towards post-positivism, outperformed girls in the examination. Although the boys scored an average of only 41%, it was significantly better than the girl's average score of 34%. I regard their better examination performance as evidence of better coping, and ascribe this to a tendency amongst boys towards post-positivism, as revealed by the NOS questionnaire, where the boys scored significantly higher than the girls with regard to the developmental subscale. I therefore argue that in general, the boys had a *tendency* towards post-positivism regarding their understanding of the developmental nature of science. I thus propose that the boys' tendency towards post-positivism can explain their better examination performance. This conclusion is in line with results of Lin and Chiu

(2004), who found that post-positivists outperform empiricists in conceptual problem solving. Post-positivists have a broader view of how science principles are related and this enhances problem solving.

However, the classification of individual learners as post-positivist and empiricist did not give a clear indication of better problem solving skills amongst post-positivists. Also, the mere fact that high achieving post-positivists, low achieving post-positivists, high achieving empiricists and low achieving empiricists co-existed, supported the absence of a statistical significant correlation between the overall NOS score and achievement in the examination. The classification may be an oversimplification under conditions of general poor understanding and poor performance as those exposed by the diagnostic test and interviews.

Career choices

Most learners chose to focus on careers outside the Physical Sciences. I propose that learners' negative attitudes lead to avoidance of careers in the Physical Sciences. The ultimate coping strategy seemed to be that learners chose careers that do not involve the Physical Sciences as a way of trying to cope with or avoid transitional problems relating to Physical Science. Ironically, the best achiever in Physical Science was not attracted to a career in the Physical Sciences. In the interviews, the two learners who did choose careers in science were both high performing boys. This supported the assertion that boys were coping better.

6.3.4 Conclusion

Learners in this study who were doing grade 9 Natural Science in 2005 were greatly disadvantaged by the curriculum that did not prepare them adequately for grade 10 Physical Science. The transition from Natural Science in GET to Physical Science in FET was described in terms of the gap model proposed by Rollnick et al. (1998). The discontinuity at the interface between grade 9 and grade 10 was described as the articulation aspect of the gap while the progression aspect of the gap described the mismatch between the output of the GET phase and the requirements throughout the FET phase. The mismatch of content, assessment and teaching strategies which characterized the transition ruled out the possibility of a smooth transition; the characteristics of the transition resulted in negative experiences and poor coping.

Document analysis confirmed the gap between C2005 and the NCS regarding science content knowledge as well as assessment strategies. The lack of prescribed content in the GET phase led to poor understanding at the articulation. Inevitably, the poor understanding at the articulation of the gap snowballed throughout the progression as learners had no base onto which they could construct new knowledge. The continued poor understanding was reflected by poor grade 11 examination scores and poor performance in the diagnostic test taken in grade 12.

Regarding assessment, the discontinuity was not limited to the articulation of the gap, but persisted throughout the progression. The significant difference in the way continuous assessment contributed towards the final mark in grade 9 and grade 10 (75% and 25% respectively) probably contributed towards the huge retention rate in grade 10. Furthermore, it is well known that parents contribute greatly towards their children's achievement in continuous assessment (which includes homework, assignments and projects) and therefore it was relatively easier for learners to pass grade 9 than to pass grade 10. Furthermore, the emphasis on formative assessment in the GET phase did not support the development of study skills required for the summative assessment in the FET phase, as confirmed by learners' admitting that they studied by 'cramming'. The high retention rate in grade 10 could therefore be attributed, amongst other factors, to the assessment gap, as well as the knowledge gap at the interface of the GET and FET.

There was a significantly better examination achievement amongst boys. The boys also scored significantly higher on the developmental scale of the NOS questionnaire. I therefore argue that the boys' tendency to be post-positivist resulted in better problem solving skills, which led to their better achievement in the examinations and better coping with the transition.

Initially, there was an increase in interest shown in science from grade 9 to grade 10, but this interest declined as learners progressed to grade 12. I propose that the decline in interest in Physical Science was caused by a lack of practical work, poor understanding, poor performance, teacher centred lessons, and a loss of close student-teacher relationships. The learners themselves described the transition as difficult.

From interviews, it was clear that the learners *believed* that their poor understanding was caused by not doing experiments in class. The learners' firm belief in the value of experiments was supported by their high scores on the 'testable' scale of the NOS questionnaire. Furthermore, the learners' wish for experimental work agrees with Gabel (1999) who argues that concepts in science, chemistry in particular, are abstract and difficult to explain without the use of analogies or models. However, I believe that experimental work would not solve all problems. Though essential, experiments should not be seen as an alternative for basic content knowledge and conceptual understanding. After all, science is a difficult subject, even for privileged learners who do all the experiments in class.

In the diagnostic test, when faced with problems of conceptual understanding, most learners resorted to guess work and rote application of concepts and algorithms. Once again, the reason was probably complicated. Firstly, the lack of foundational knowledge inherited from C2005 can be regarded as a fundamental factor. Of course, this could be compounded by unproductive teaching strategies as was confirmed by lesson observations and interviews with learners. The poor quality of teaching in the FET is a problem in its own right, but it certainly compounded transitional problems.

Also, teachers' limited knowledge placed serious restrictions on the extent to which the learners were exposed to the processes of investigation pursued by South Africa's learner-centred education policies. The government had long conceded that Black science teachers' subject knowledge and professional confidence were generally poor, as "a cycle of mediocrity perpetuates itself through their efforts in the classroom" (Government Gazette, 1995, p31). It was further pointed out in the *Government Gazette* that if this cycle were wasteful from an educational point of view, it was catastrophic from the perspective of national developmental needs. There is a need for 'a significant empirical agenda' (Apple, 1986) on science teachers. This agenda includes Rogan's (2004) appeal for greater initial text 'structure' for teachers. Ultimately, what is needed is a comprehensive and far-reaching teacher development initiative (Stoffels, 2004).

The class of 2008 obtained disappointing results in the final grade 12 Physical Science examinations. Both provincial and national results of the class of 2008 are given in Appendix M. In Gauteng only about 37% of candidates obtained 40% and above, while nationally the figure is even lower at about 29%. Appendix N gives the pass requirements for the National

Senior Certificate (NSC). The results for Physical Science are disappointing considering that it would require at least three subjects at 40% or above for one to obtain the NSC. Finally, the poor performance in the final Physical Science examination ultimately confirmed the difficult transition to the FET phase and poor coping throughout the FET phase for the class of 2008.

6.4 LIMITATIONS TO THE STUDY

Amongst the limitations of the study were that it was a case study of one school. Furthermore, the school was within a previously disadvantaged community. The effects of the teachers' and students' backgrounds on scientific understanding were not explored. Transitions could very well have been smooth in privileged communities where schools were well resourced and teachers well trained. Also, in the diagnostic test, learners were not given the actual samples of the chemicals, which might have influenced the responses and I acknowledge these as weaknesses in the study. As the findings are based on the Natural Science learning area and the Physical Science subject some findings are likely to be common with what would be found with other subjects, but some of them may be unique to Natural Science and Physical Science.

6.5 DIRECTIONS FOR FURTHER RESEARCH, IMPLICATIONS FOR SCIENCE EDUCATION AND RECOMMENDATIONS

There is a need for more longitudinal studies of this nature to understand learners' difficulties to cope with curricula, especially when new curricula are introduced.

The interface between the GET and FET appears to be the critical time when learners make decisions about subject and career choices, so it is important that the excitement about science with which they enter the FET phase (grade 10) should be built upon by offering exciting science programs that are suitable for adolescents.

It is of critical importance that curriculum developers should concern themselves with matching of curricula across phases. Assessment strategies across phases should also be aligned. Comprehensive planning is one of the key elements to successful transitions, as Patton and Dunn (1998) noted when they explained Halpern's model of transition. Such comprehensive planning should precede curriculum changes to minimize hazardous transitions. Well planned transitions would minimize discontinuity in the curriculum and create an atmosphere that is conducive to progress in the classroom.

The Department of Education could assist science teachers in making their teaching more relevant, meaningful and interesting. Teacher training courses should incorporate recent research findings in science education. In-service training should be held with the aim of improving teaching strategies and content knowledge. Promoting students' understanding of the NOS is might result in higher conceptual problem-solving ability (American Association for the Advancement of Science, 1989), which would facilitate a smooth transition in science. Diagnostic tests on basic concepts in Physical Science should be introduced in order to diagnose obstacles to the understanding of science concepts.

Grade 9 Natural Science and grade 10 Physical Science educators could form cluster committees with the aim of trying to close the gap at the interface of the two phases. To facilitate a smooth transition, the committees should ensure that GET and FET educators have comprehensive plans that include a thorough needs analysis of learners and the receiving setting.

Finally, all role players should work towards creating manageable transitions for science learners into the FET phase. Smooth transitions could encourage more learners to choose scientifically based careers. In the long run, well informed and well planned support to science teaching will bear fruits of improved performance in science, economic growth and a scientifically literate community.