Science and Mathematics Education Centre

Investigating the Introduction of the International Baccalaureate Diploma Alongside the Existing Local Curriculum: Examining the Intended, Implemented and Achieved Science Curricula

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ABSTRACT

My thesis describes a two-year study carried out during the introduction of the International Baccalaureate Diploma (IBD) alongside the local Higher School Certificate (HSC) at a school in New South Wales, Australia. The study examined the intended, implemented and achieved science curricula to provide a formative evaluation that could be used by the school to improve students' experience and achievement, and a summative evaluation that could be used to inform other schools considering the implementation of the IBD alongside a local curriculum.

My research represents one of only a few studies that compare the IBD with another programme, and the only study, to date, in Australia. It is also one of the only studies that compare senior science programmes in any country. Methodologically, my study supports previous research that has successfully combined the collection of quantitative and qualitative data in a mixed-method approach.

Keeves' (2004) model was used to provide a framework to help to describe the curricula in terms of the antecedents and context in which they are embedded. A modified version of Halls' (1971) model was used to compare the aims, objectives and content of each of the curriculum. Gilbert's (2004) model, adapted from the Australian Council of Education Research (2001) model, was used to compare the skills required by each of the science programmes. To discern the depth and breadth of the science courses examination questions were compared and contrasted.

To examine the implemented curriculum, the views and experiences of the teachers and students participating on each of the programmes (IBD and HSC) were sought. Data related to the views of the participating teachers were gathered using in-depth interviews, observations and anecdotal evidence. To examine the students' experience of science in each programme, their perceptions of the learning environment were assessed using the Science Laboratory Environment Instrument (SLEI). Focus group interviews with students enrolled on each of the science programmes were used to triangulate, embellish and clarify the questionnaire results.

To examine the achieved curriculum, data were collected using the Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA), a purpose designed attitude instrument and students' University Admissions Index score. Finally, a questionnaire was used to examine whether students enrolled in the IBD and HSC programmes felt that the Year 10 science programme had adequately prepared them for their senior science course.

The results indicated that the IBD provided a more traditional, mathematically based science course with rigorous, mainly external assessment, whereas the HSC provided a broader, more historically and socially based science course. Concerns were raised by both the IBD and HSC teachers with respect to the content-laden requirements of both of the programmes. IBD teachers raised issues related to the resources available and the need for adequate professional development. Students' views of the learning environment indicated that those in the IBD course generally had more positive views than their HSC counterparts. In terms of the achieved curriculum, the results indicated that there were some differences between the two programmes, with IBD students attaining a higher University Admissions Index score and indicating an increased likelihood of selecting a science-related career than their HSC counterparts. Finally, the results indicate that there are issues related to the Year 10 science programme (designed to suit the needs of the HSC programme) that may need to be addressed to better prepare students embarking on the IBD programme.

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GLOSSARY OF TERMS

ACER	Australian Council for Education Research
AMI	Adult Multiple Intelligences Study
AP	Advanced Placement.
BOS	Board of Studies, NSW.
GCSE	General Certificate of Secondary Education, UK.
HSC	Higher School Certificate
IBD	International Baccalaureate Diploma
IBO	International Baccalaureate Organisation.
ICT	Information and communication technology
ISA	International Schools Association.
ISES	International Schools Examination Syndicate. (later became the IBO)
MI	Multiple Intelligences
MICA	Multiple Intelligences Checklist for Adults
NSW	New South Wales, Australia
PISA	Programme for International Student Assessment
ROSE	Relevance of Science Education study
SLEI	Science Laboratory Environment Instrument
TIMMS	Third International Mathematics and Science Study
TOK	Theory of Knowledge, IBD programme unit of study.
UAI	University Admissions Index
UK	United Kingdom of the British Isles and Northern Ireland
UNESCO	United Nations Educational, Scientific and Cultural Organisation
US	United States of America

CHAPTER 1

INTRODUCTION AND OVERVIEW

Education can be viewed as a service commodity within a consumer driven society, whereby the students and parents are the service users. For the most part, independent schools in Australia are running, by necessity, as business enterprises and are influenced by market forces. There is a need, therefore, for schools to continually find niche markets in which they are able to compete for custom. The principle of parent choice of curriculum has already been accepted in most Australian states.

At present, individual curriculum is mandatory for each Australian state, which has lead to concerns related to standards, comparable assessments, and students moving between states or internationally. To overcome the issues related to the transferability of qualifications and movement between states, and to capture a niche market, some private schools have opted to include the International Baccalaureate Diploma (IBD) as an alternative to the state senior curriculum (Pimm & Selinger, 1995). The International Baccalaureate uses an internationally devised curriculum with high academic standards that are recognised around the world. A list of all abbreviations used in this thesis can be found in the Glossary of Terms (Contents section, p. xiii).

Blackwood School, a pseudonym to maintain anonymity, is one such school that has decided to offer the International Baccalaureate in addition to the local curriculum. My thesis describes a two-year study of two groups of science students enrolled at Blackwood School. One group was enrolled in the traditional New South Wales Higher School Certificate (HSC) and the other was enrolled in the International Baccalaureate Diploma (IBD). The main purpose of this study was to compare the science curricula and how they were enacted at the classroom level; and to investigate whether including the IBD programme at the school provided students with opportunities that might not be offered through the traditional HSC programme.

The research reported in this thesis evaluates and compares documents and examines issues associated with teaching science in the HSC and IBD programmes in terms of the curriculum, student perceptions of their learning environment, and outcomes in terms of career choices and achievements.

This chapter introduces the thesis using the following headings and section numbers:

1.1 Context of the Study;
1.2 Significance of the Study;
1.3 Research Objectives;
1.4 Limitations of the Study; and
1.5 Overview of the Thesis

1.1 CONTEXT OF THE STUDY

To understand the importance of this study and to provide a background to help make sense of the comparisons, this section seeks to briefly set the scene.

Section 1.1.1 provides information about Blackwood school, the site of the present study. Section 1.1.2 summarises the introduction and delivery of the second curriculum, the IBD, at Blackwood School and the preparations that were required to make it possible.

1.1.1 Blackwood School

Blackwood School, the site selected for the present study, was established in 1901. This school is a non-selective, independent, K-12 girls' school located in a northern suburb of Sydney. It has a junior school attended by 200 students and a secondary school made up of 800 students, over 250 of whom are in Years 11 and 12. At the time of the study, 100 of the students were full-time in-school boarders, most of whom were senior students and the majority of whom were from rural NSW or overseas.

In the northern suburbs of Sydney, education is considered to be an important commodity. Within a 10 kilometre stretch of highway there are four, high-fee paying, independent girls' schools of excellent academic standing. In recent years, the schools have assumed a more businesslike culture, in which marketing has become of paramount importance. At Blackwood School this is evident from an increase in marketing staff from one part-time person (as recently as six years ago), to a team of five full-time members. At the school a professional website has been developed, a branding exercise was carried out to ensure a truly corporate image and all publications are now of high quality. Quite simply, the business plan involves ensuring an excellent product to encourage more student enrolments.

In 2005, to meet a niche market within the plethora of excellent girls' private schools, Blackwood School sought to introduce the IBD to extend its appeal to the increasing number of transient families and to international overseas students. The families whom were to be targeted included those who were migrating, moving inter-state, or travelling for short or long terms.

1.1.2 Introducing the IBD at Blackwood School

It is within this context that Blackwood School decided to introduce the IBD programme. There were two driving forces that influenced this decision. First, there was a need to offer opportunities for academic excellence and, second, there was a need to maintain financial viability by keeping abreast of market forces. The local suburbs surrounding Blackwood School, in which the population is mainly professional, were experiencing changes in demographics from a more Anglo population to a more multicultural one. Also, the population was becoming more mobile due to international employment demands. It was recognised that there was a degree of concern among parents, whose children were anticipating that they might attend a university overseas, that the local HSC curriculum may not be fully understood or recognised.

The inclusion of the IBD at Blackwood was considered to be appealing for two reasons. First, the transferability of qualifications between countries and states was viewed by the management of Blackwood School as a good marketing strategy that was likely to be appealing to the increasingly mobile local population. Second, it was felt that the IBD programme might serve to attract overseas families looking to enrol their students in Australia.

It was at this point that the Blackwood School applied for approval from the governing body (the International Baccalaureate Organisation, IBO) to introduce the IBD. This process involved considerable administrative work and proved to be rigorous. To apply for approval, the school was required to make a high financial outlay and to assemble documentation to send to the regional office of the IBO. In turn, the IBO sent authorities to visit the school to provide feedback. The document preparation and subsequent scrutiny by the IBO has been known to take up to year and success at this point is not guaranteed. To be accepted by the IBO the school was required to demonstrate that it had fully understood the criteria and conditions and was able to meet the standards set.

Following acceptance by the IBO the school was then required to manage issues related to setting up the programme. To meet the requirements of the IBO, after the school visit, a building plan was initiated so that the library and computer facilities were improved and extended to include private study areas. This project was undertaken to provide students with better research facilities and areas that they could use to carry out individual private study. The plan also included the purchase of a new property which was converted into a senior boarding house to create more classroom space to house the IBD classes. Approval was granted only after recommendations, made by officials during a visit to the school, had been complied with.

Once approval had been granted, serious marketing to the school and wider community became a key issue to ensure that there were sufficient enrolments to make the programme viable. Although not the usual practice of schools adopting the IBD, Blackwood School decided that students would not be charged additional fees and that the school would bear the cost of the IBO school membership fees, student fees and examination fees (Bagnall, 1994: Doherty, 2009; Mathews & Hill. 2005).

Introducing the IBD to the school involved key organisational issues, including: timetabling and rooming; appointment of staff; student team building; staff training;

and marketing. All of these issues were required to be addressed and overcome prior to the commencement of the IBD programme. The timetabling and rooming for the IBD subjects needed to fit alongside an already established structure and was highly dependent on the number of enrolments, which would not be available until late in the year. According to Bagnall (1994) most Australian schools have entry requirements for the IBD because of its rigorous demands (Bagnall, 1994). Blackwood School, however, decided that, as a non-selective school, the IBD would be available to all students regardless of ability.

Members of the academic staff within Blackwood School were invited to submit expressions of interest to teach the new IBD programme. They were required to submit their qualifications and to be interviewed, during a site visit, by IBO representatives. Once an IBD coordinator and academic staff had been appointed, staff training commenced. To introduce senior staff and academic staff to the philosophy and ethos of the IBO, they were required to attend a training workshop in New Zealand at a week-long IBO-run Asia-Pacific Conference (attended by other International Baccalaureate staff from around the world). Prior to the commencement of teaching, all of the IBD teachers were required to attend these subject-specific professional workshops, designed to introduce them to the assessment and reporting procedures required by the IBO. These workshops provided valuable opportunities for teachers to network with other teaching staff from around the world. The science teachers from Blackwood school agreed that the workshops were valuable for networking and helped them to understand the complex administrative requirements for the internal assessment.

To ensure that the enrolment numbers would be viable, marketing to students and their parents became a priority. During their visit, IBO representatives gave a presentation to interested students and parents, which was well attended. This presentation provided information about the holistic ethos of the programme and its international success. At the Year 10 information evening for parents and students, both the HSC and IBD programmes were presented. A further information evening was then held for those parents and students who were interested in finding out more information related to the IBD programme. This meeting was also attended by the IBD academic staff, who attempted to answer specific subject-related questions and

to help guide student subject choices. Due the relatively low number of students interested in enrolling in the programme (eighteen girls), some of the curriculum subjects were removed from the original selection (such as physics).
The deadline for subject selection for Year 11 courses were requested by the end of Term 3. From this point, the prospective IBD students, led by the IBD coordinator, were given considerable encouragement and support as a cohort, to help them to cope with any uncertainty stemming from being a pilot group. A team building retreat was held for the IBD students at the end of Term 4 of Year 10 to further help the students to bond and to fully equip them for the start of the new programme.

This section has introduced the school in which the study took place and has described some of the issues that were addressed prior to the introduction of the IBD at the school. The next section identifies the significance of the present study.

1.2 SIGNIFICANCE OF THE STUDY

An extensive review of the literature indicates that there are issues facing Australian educational curriculum delivery. For the consumer, issues are related to consumer choice and concern about standards and the transferability of the different state-based qualifications in an increasingly mobile society (Australian Council for Educational Research, 2006; Buckingham, 2006; Kemp, 2006). During this time there were also ongoing arguments and debates concerned with the Federal Government introducing a National Curriculum (Australian Council for Educational Research, 2006; Barcan, 2004; Farelly, 2005). Introducing the IBD into Blackwood School provides a choice of curriculum to parents and students.

The IBD is not only an established curriculum structure but also an international curriculum that enables the transfer of qualifications from one country to another. The purpose of this study is to compare the IBD with the existing local curriculum in a bid to ascertain whether it is viable or advantageous for a school to incorporate both curricular simultaneously. The study is significant in several ways.

- There are many comparative studies of curricula both internationally and nationally, however, this study is significant in that it is the first comparative studies between two curricula being run simultaneously within one school in Australia, particularly within the curriculum area of science.

- This research is significant as it uses a combination of qualitative and quantitative research methods to compare the views and experiences of the stakeholders, students and teachers, within the two programmes.

- A major issue to be addressed in science education is the concern (in both Australia and much of the western world) that many students, particularly girls, are not choosing careers in science. Consequently there is a lack not only of scientists and engineers but also science teachers, which exacerbates the problem for the future. Both the curricula and teaching approaches have been varied over the past 20 years in attempts to attract students into this field, with only limited success (Howes, 2002; Kelly, 1981; Whyte, 1986). This research is significant in that it examines whether these two curriculum differ in terms of their likelihood of attracting girls to a science career.

- This research is likely to be of significance to Blackwood School in several ways:

    - A comprehensive understanding of the differences between the two science courses, in conjunction with the perceptions of the students concerning their chosen programme, will inform future marketing of the programmes. This knowledge could also assist future students to make a more informed choice of programme.

    - The perceptions and views of the students, concerning their science learning environment and attitudes will be informative for science teachers. The results could assist the school to improve the teaching and learning of science within both programmes.

    - Finally, it is of significance to Blackwood School to determine whether the state junior science programme prepared the students adequately for both the IBD and HSC.

1.3 RESEARCH OBJECTIVES

The research reported in this thesis examines and compares two science curricula, the IBD (which was introduced at the school at the commencement of the study) and the HSC (the local curriculum offered state-wide) both of which were running concurrently at Blackwood School over the two years of the study. Participating students were all studying science on one of the two programmes that were being offered.

The first research objective was developed to investigate the differences and similarities between the IBD and the HSC. The research objective was designed to provide an overview and understanding of the two curricula.

Research Objective #1

> To investigate whether differences exist between the IBD science programme and the HSC science programme in terms of the curriculum content, objectives and assessment requirements.

The second objective sought the views of the science teachers participating in the two programmes with regards to their previous teaching experience and their new challenges within the parallel programmes.

Research Objective #2

> To examine teachers' views about the issues involved in teaching, learning and assessment in the IBD and HSC programmes at the school.

The third objective sought the views of the science students participating in the two programmes with respect to their experience within the learning environment. This research objective was designed to provide an understanding of the students' perceptions of the practical science experience.

Research Objective #3

> To investigate whether differences exist for students enrolled in IBD and HSC programmes in terms of their views of the learning environment.

Of international concern is the lack of popularity of senior science (particularly physical science) subjects amongst girls and the subsequent lack of students following science-related career paths. Examining the perceptions of the students for whom science was compulsory (IBD) compared to those who had chosen to study science (HSC) could give insights into how students' experiences can be improved. To this end the fourth objective was delineated to examine a range of outcomes.

Research Objective #4

> To examine whether the outcomes of students enrolled in the IBD and HSC science programmes differ in terms of:
>
> a) Their propensity and desire to pursue a career in science;
> b) Whether the science programme lived up to their expectations; and
> c) Achievement according to the University Admissions Index.

To provide information with which to enhance and improve the students' experience of junior high school science in terms of attitude and preparedness, and hence raise both the popularity and the academic excellence of science at Blackwood School, the fifth objective was developed:

Research Objective #5

> To investigate whether the Year 10 science programme provides an enjoyable experience and whether differences exist for students enrolled in IBD and HSC in terms of adequate preparation for their selected programme.

These objectives were addressed over a two year period following the progress of the first cohort of students participating in the IBD programme and their HSC counterparts. The next section provides an overview of the limitations of the study.

1.4 LIMITATIONS OF THE STUDY

Although the limitations of the present study are discussed more fully in the concluding chapter, this section provides a brief overview of the limitations. The study was limited first by the low enrolment of students on the IBD programme. This had a two-fold effect. First, the sample size of the study presents potential limitations because it was neither sizable nor representative of the full range of high school students. Therefore, it is unclear whether the findings in this study would apply to other schools introducing the IBD alongside the local curriculum in Australia. Also the power of statistical analysis was greatly reduced by the limited sample size. To overcome this wherever possible, rich, in-depth, qualitative data was gathered to enlighten the findings of the quantitative data.

Second, the reduced enrolments in the IBD program necessitated, for economic reasons, a reduction in the number science programmes offered. Only two sciences, biology and chemistry, were offered within the IBD. As the intended physics teacher I was no longer required to teach on the IBD programme. Hence, although, as researcher, I was still a member of the school staff, I was unable to compare the experience of teaching in both programmes from a personal perspective as was originally intended.

1.5 OVERVIEW OF THE THESIS

The design, development, implementation and findings of this study are presented in six chapters. Chapter 1 introduces and provides a rationale for the study, and states the research objectives. As well, this chapter pre-empts the limitations of the study.

A review of the literature pertinent to various aspects of the study is presented in Chapter 2. This chapter reviews literature relevant to science education, and to curriculum comparison and evaluation, learning environment research, and

Gardner's theory of multiple intelligences. The chapter also provides a historical view of the IBO leading to the development of the IBD. Finally, the chapter reviews literature related to national and international concerns about the lack of participation in science education.

Chapter 3 outlines the research methodology, the design of the study and the methods used in the current study. Also described in this chapter are the phases of the study, the student and teacher sample, the data collection (both qualitative and quantitative), the instruments used and the procedures used to analyse the data. Finally, details relating to the ethical considerations surrounding the study are provided.

Chapters 4 and 5 provide the results of the study. Chapter 4 details an in-depth comparison of the intended IBD and HSC science programmes. The chapter begins by placing the two programmes into context by describing some of the major issues related to Australian education at the time of the study. The chapter goes on to introduce both of the programmes and to describe the structure and history of each. The remainder of the chapter provides an in-depth comparison of the science curricula with a focus on the physics programme. The comparison examines the individual syllabus content, aims, objectives, specified skills, recommended delivery and assessment requirements.

Chapter 5 provides the results pertaining to implemented and achieved curricula. To examine the implemented curricula, the views about the learning and teaching experiences of the participants are sought from students and staff. In both cases, perceptions of the two programmes and issues related to their implementation are investigated. To examine the achieved curricula, three outcomes are examined, these being, students' enjoyment of their respective programme, the likelihood of the programme encouraging the student to pursue a career in science, and students' final academic outcomes (University Admissions Index). Finally, this chapter reports the results related to the students' views of the appropriateness of the science educational experience provided at the junior high school level, in terms of enjoyment, and preparing them for their selected programme.

Chapter 6 is the concluding chapter and provides a summary of the thesis, together with a discussion of the limitation and implications of the study. Also, this chapter provides some recommendations for further research and recommendations for the implementation of future parallel programmes.

CHAPTER 2

REVIEW OF LITERATURE

This chapter provides a review of literature related to the present study. The literature review has taken several directions, including: defining curriculum; examining a range of models for curriculum evaluation and comparison; and the development and implementation of the International Baccalaureate Diploma (IBD) programme, both internationally and in Australia.

Within Australia, the debate for a national curriculum continues to this day. The International Baccalaureate programme has featured as an educational alternative in the search for an ideal national curriculum (National Research Council, 2002; Swain, 2006). Despite the failure of the introduction of the national curriculum, a number of private schools have opted to offer the International Baccalaureate Diploma (IBD) alongside the state curriculum, as an alternative, internationally recognised, curriculum. By 1992, thirteen schools in Australia offered the IBD and an average of 75% of the students enrolled in this curriculum were Australian rather than international students (Bagnall, 1994). In 2008 there were 56 Australian schools that offered the IBD, 14 of which are located in New South Wales (International Baccalaureate Organisation, 2009). The IBD is seen as an appealing (and marketable) alternative because it is internationally recognised, makes transferring between the states more possible, and is acknowledged for both its academic standing and innovative, holistic approach. In 2005, Blackwood School joined the growing number of schools that offer the IBD as an alternative to the local High School Certificate (HSC) of New South Wales (NSW).

This thesis describes a two-year study that compares and evaluates the two science programmes offered within Blackwood School in terms of the intended, implemented and achieved curriculum. To inform this study, a literature review of pertinent areas was conducted. This chapter reports this literature review using the following headings:

2.1 Science Education in the 21st Century;
2.2 International Baccalaureate;
2.3 Curriculum Evaluation and Comparison;
2.4 Study of Learning Environments;
2.5 Multiple Intelligence Theory, Learning Styles and Career Choice; and
2.6 Chapter Summary.

2.1 SCIENCE EDUCATION IN THE 21ST CENTURY

Life in the twenty first century places a growing demand for individuals to engage with science topics such as health and climate change. To deal with these changes new approaches to science education are taking place internationally. In Australia, science literacy, supported by science education, is seen as a priority because "progress and sustainability will be enhanced where the community is scientifically literate" (Australian Council of Deans of Science, 2004, p. 1).

In recent years there has been a progressive decline in student enrolment in the physical sciences, at both school and university levels, in many industrialised countries, including, Australia (Ainley, 1993; Fullarton, Walker, Ainley & Hillman, 2003; Walker, 2005), Europe (European Commission, 2004) and the US (National Science Foundation, 2002, 2004). There is currently an international shortage of scientists, engineers and science teachers and universities around the world are closing departments of physics (Butler, 2008). In addition, there is a tendency for fewer girls than boys to enrol in science courses, particularly in the physical sciences (Fullarton & Ainley, 2000). These problems have caused considerable concern to governments around the world because of the importance of scientific knowledge to a country's economy.

Of major concern to the present study is the issue of declining numbers of students enrolling in science-related subjects (discussed in Section 2.1.1); gender equity in science (discussed in Section 2.1.2) and students' experience of their science curriculum (discussed in Section 2.1.3).

2.1.1 Declining Numbers of Students in Science

Science has not been a popular high school subject over the past thirty years, particularly for the physical sciences and amongst girls (Butler, 2008; Campling, 1989; Kelly, 1981; UNESCO, 2007; Whyte, 1986). As a result, many students are not following scientific career paths, contributing to the international deficit of scientists.

As far back as 1963, Snow recognised an increasing gulf between science and the general public. In his paper on the changing roles of mathematics and science in society, British author and scientist, C.P. Snow, wrote:

> Literary intellectuals at one pole, at the other, scientists … Between the two, a gulf of incomprehension - sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding ... This polarisation is sheer loss to us all. To us as people, and to our society (Snow, 1963, p. 53).

In 2005, George Walker, director of the IBO, also recognised the "worrying flight from science in schools and universities" (Walker, 2005, p. 6). He reported that the most popular subjects are now the humanities and that, although the quality high performing science students were being maintained, approximately one third of the students were failing their compulsory science subject within the IBD.

In the UK over one thousand, 18 year-old students were surveyed to examine reasons for their choice of science or engineering occupations (Woolnough, 1994). According to Woolnough (1994), the most influential factor was the quality of the science teaching that they had experienced in schools, in association with personal encouragement, laboratory work and intellectual challenge. Two years later the survey was developed to discover reasons why students did not choose a career in science and found that the choice was not because students were opposed to science, but rather, they had a preference for a career in another field (Woolnough, 1996). These findings have been replicated in other countries such as Europe (European Commission, 2004), Finland (Lavonen, Gedrovics, Byman, Meisalo, Juuti & Uitto, 2008) and Australia (Young, Fraser & Woolnough, 1997).

Another study, carried out in Europe, found that, in developing countries, science careers are often perceived as unattractive, isolated in a laboratory and low status (Schreiner & Sjoberg, 2007). A recent study, carried out in Finland and Latvia to examine students' motivations and career choice in science, indicates that students found school science difficult and uninteresting and science careers to be unattractive (Lavonen et al, 2008). In addition, a primary goal of many of the students was high earnings, which they did not feel could be achieved by pursuing a science career. According to the findings of the OECD (Organisation for Economic Cooperation and Development, 2005), students are often unaware of the wide diversity of careers available to them if they were to study science.

A recent, in depth study of students in Finland and Latvia, investigated students' motivations and career choice in science. The results confirmed that these students found school science difficult and uninteresting and science careers to be unattractive. In general, student's goals were high earnings, which they did not perceive to be achieved by pursuing a science career (Lavonen et al., 2008).

The results of a study conducted in the UK indicated that not only should careers education and guidance begin much earlier in secondary schools but it should be targeted at parents as well as pupils if girls are to feel free to choose non-traditional career paths (Opportunity 2000, 1996). Employers approached in the UK study believed that the quality and quantity of careers education and guidance in schools is a key to attracting more girls into science.

A review of the literature indicates that, to date, only one study has investigated students' choice of science subjects within the IBD. The study compared two schools, one in Portugal and one in Finland, selected because of their contrasting enrolment and achievement (James, 2007). The study examined factors such as: the influence of peers and careers advisors on subject choice; the perceived difficulty of subjects; and career requirements. The sample included 82 students, selected from two schools in each participating country. From a total of 21 factors, the top three influences on students' selection of subject was (1) university course requirement, (2) interest and (3) career requirement. The study found that parents had more influence on student's choice of a subject than the careers advisor or IBD coordinator. Of 21 factors, good teaching quality was considered to be sixth. Biology and chemistry students both placed university and career requirements ahead of interest; however physics students placed interest first. Media influence and peer pressure was not considered to be influential in the respondents' decision making. Some students from the study would have preferred to enrol in three science-related subjects but the IBD structure restricted them to two (James, 2007). The present study examined students' aspirations at the beginning and at the end of the two-year programme to provide an indication of whether either the IBD or HSC were more likely to encourage students to pursue science-related careers.

2.1.2 Gender Equity in Science

There has been growing concern for the discrepancy in the outcomes and achievements of boys and girls in science education (Howes, 2002; Parker, Rennie & Harding, 1995; Rennie, Fraser & Treagust, 1999). The need for an inclusive science education, where students are offered opportunities to experience a wide range of learning activities and assessment tasks, was identified as a social justice issue in Australian education (Goodrum, Hackling & Rennie, 2000). This issue was addressed during curriculum reform in NSW through clear statements in the syllabus and supporting documentation (Board of Studies, 2002a).

The most recent Programme for International Student Assessment (PISA) study indicated that, although girls performed better in the general literacy section when compared with boys (Organisation for Economic Cooperation and Development, 2007), this performance was not evident in the science section, despite the science questions requiring a high level of literacy. According to the Organisation for Economic Cooperation and Development (2007), this could suggest that the subject matter involved in the testing is more engaging for boys than for girls. In Australia, the results of the PISA showed virtually no gender differences in students' general achievement in science (Organisation for Economic Cooperation and Development, 2007) indicating perhaps that science ability is not the cause of lower enrolment of girls in science courses.

In many countries around the world, trends suggest that the number of girls choosing medicine and environmental and biological sciences as a career is currently increasing and more boys than girls are selecting careers in physics and engineering (Schreiner & Sjoberg, 2007). In Australia, however, national figures indicated that although the same number of girls studied senior biological sciences as boys, 50% more Year 12 girls enrolled in independent schools were choosing to study physical sciences than their counterparts in government schools (Fullerton & Ainley, 2000). In NSW statistics indicate a steady trend in the candidature, with twice as many girls taking biology as boys. In chemistry and physics however, girls make up 40% and 20%, respectively, of students taking up these subjects (Board of Studies, 2007).

More recently, United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2007) sought to address the international concern over girls not selecting science subjects, and hence careers, by producing a training module to assist teachers and career advisors. Research suggests that girls do not have the same opportunity as boys for participating and achieving in science education (Howes, 2002).

Sandland's (2001) study of IBD enrolments indicates that, although a science subject is compulsory, female students follow international trends with more girls enrolling in biology, and fewer girls enrolling in physics or electing to enrol in an additional science. This trend was also found in a more recent study of IBD students in Finland and Latvia (Lavonen et al., 2008). The present study, carried out in an all-girls school, will examine whether either of the programmes (IBD and HSC) are more likely to encourage students to pursue science as a career in the future.

2.1.3 Student Experience and Perspective of their Science Curriculum

Given that the present study aimed to examine students' experiences in the IBD and HSC science programmes, this section reviews literature related research that has investigated aspects of the science curriculum that were of interest to teenage students. In an attempt to understand students' perspectives of an interesting curriculum, Schreiner & Sjøberg (2007) carried out a cross-cultural comparative project to examine young peoples' views of science and technology. Known as Relevance of Science Education (ROSE), the study sought students' views across 40 countries about studying science and the content that they feel should be covered. In a bid to determine what topics and teaching methods might have the potential to inspire and excite 15 year-olds, students were given a questionnaire on which they indicated their values, interests and attitudes to science and technology. It emerged that, generally, young people are interested in many self-centred topics, such as environmental issues and dreams, and these might function as gateways into science teaching and learning.

Australia participated in this project and data was collected from some 800 students. Of this sample only 42 of the surveys were valid as many were submitted incomplete. This, unfortunately, did not imply a high interest in science and technology for Australian teenagers (Schreiner & Sjøberg, 2007).

Further research into student perspectives on their curriculum was reported by Curtis (2002) in the UK, who found that the General Certificate in Secondary Education (GCSE) was a traditional, content laden syllabus. This was a source of frustration to both science teachers and students because of the lack of flexibility in the science curriculum. Curtis stated: “Students lose any enthusiasm they once had for science. Those who choose to continue with science, post-16, often do so in spite of their experiences of GCSE rather than because of them” (Curtis, 2002, p. 8). The report identified that the science curriculum needed to be more relevant to students’ everyday life, and that “…instead of learning endless facts, they should engage in popular scientific debate, such as those over GM food and genetic cloning” (Curtis, 2002, p. 8). The report also stated that current coursework was viewed by students as boring and pointless.

The ROSE project and the Curtis report both indicate that teenage students are not engaged with the content of their science curricula. It would appear that students often do not see the relevance between curriculum content and their own lives. In a bid to address these issues, curriculum councils around the world have advised in that science should be made more accessible (Black, 1995; Rennie, Goodrum & Hackling, 2001; Organisation for Economic Cooperation and Development, 2005). It was generally agreed that basic subject knowledge must be identified in each science subject area, with grounding in mathematical and technological skills in order to solve problems, and for students to be 'thinking about science' requires more than the simple memorisation of definitions or theories (Australian Council for Educational Research, 2001; Conley, 2003).

Studies in curriculum reform have identified that strategies and resources alone were insufficient to ensure change, and that the teachers' perceptions and understandings were of great importance to the successful implementation of curriculum change. Wallace and Louden (1998) consider that curriculum reform should: be guided by science educators as well as professional scientists; refer to the expectations of the students; provide sufficient support and professional development for the teachers; and accommodate the range of contexts within which it is to be delivered. The present study sought to examine students' views of their respective science courses and their experiences of the various activities carried out within their classes, such as, laboratory work and independent study. The students' enjoyment of science was also considered to be an important aspect that could influence career choice.

2.2 INTERNATIONAL BACCAULUAREATE DIPLOMA

Given that the present study examines the introduction of a new curriculum, the IBD, at Blackwood School, it was considered useful to review literature related to the history of the IBD (discussed in Section 2.2.1), the Australian curriculum perspective on the IBD (discussed in Section 2.2.2) and past studies that have compared the IBD with other curricula (discussed in Section 2.2.3).

2.2.1 History of the IBD

An extensive history of the IBO was written by British educator Alec Peterson (1972), the first IBO director general (1966-1977). Peterson was attracted to the concept of an international university entrance examination which could be taken and recognised in any country. This concept was first developed in the International School of Geneva as a result of practical and educational issues faced by the teachers (Peterson, 1972). Due to the cosmopolitan nature of the student environment, teachers at the school prepared their senior students for four separate examinations, the Swiss Maturite, the American College Board, the English GCE 'A' Level, and

the French Baccalaureate. This involved providing a large number of small classes in which students in the senior years were divided into national groups, allowing programmes, geared exclusively to the specification of each national system.
According to Peterson (1972), students between 16 and 18 years of age were likely to gain the most benefit from associating with a culture other than their own. In 1951, several schools in England embraced this theory by introducing an international sixth form and the International Schools Association (ISA) was formed. The teachers in Geneva met with the ISA schools and shared their ideas of developing a specialised programme for the final years before entry to university, which could obtain international recognition. Such an examination would enable schools to keep senior students together and to teach them using a curriculum geared to the needs of an international school setting. This was hailed as visionary, as many of the international schools were unable to sustain the cost of running senior years schooling, giving students no option but to attend a boarding schools in the country of their preferred university. The proposed programme would enable international schools to run a full secondary education for students of a rapidly growing and highly mobile international community.

One of the original purposes of the teachers in Geneva was to create an international tertiary entrance qualification (Peterson, 1972). In 1962 the International Schools Association, agreed to explore the possibilities of developing a joint social studies examination, as a first step towards this new curriculum. This idea was sponsored by The United Nations Educational, Scientific and Cultural Organisation (UNESCO), and the International Schools Examination Syndicate (ISES) was established to start a new examination system.

The main problems faced by the organisers of the International Schools Examination Syndicate included: the production of programmes that suited the needs and ideals of international schools that would also be acceptable to universities internationally; agreeing on examination methods for these programmes; finding internationally acceptable examiners; guaranteeing international recognition; funding a pilot programme, and addressing parents' concerns of risking their student's chances of university entry. In 1967 the Ford Foundation provided a three year grant to establish the feasibility of an international university entrance examination, and the

International Baccalaureate (IB) was established. This provided a forum for many educators, initially American, British, French, German, Swedish and Swiss, but now from many other countries, to meet and discuss programmes unhindered by the constraints of a national system.

To help achieve acceptance by universities world-wide, the International Schools Examination Syndicate ran a six year project from 1970 to 1976. During this time, universities and national authorities were asked to grant provisional recognition to the International Baccalaureate as an entry qualification for students from international schools. A research unit was set up to monitor and evaluate the findings. At this point the name of the organisation was changed from International Schools Examination Syndicate to the International Baccalaureate Office (IBO), which is maintained to this day.

In 1971 a series of studies carried out by United Nations Educational, Scientific and Cultural Organisation, to promote international cooperation for the development of tertiary education in its member states recognised the initial success of the IB examination. "Its examination…has already secured a gratifying degree of international recognition, largely because it has considered the problems of acceptability of diplomas from the pedagogical viewpoint" (Halls, 1971, p.21). Halls applauded the intensive consultation carried out amongst the participating authorities and teachers in setting up the courses, syllabuses and final examination.

In 1997, a small UK study investigated the success of the IBD in assisting in terms of limiting disruptions to students' education. The findings indicated that students within the IBD programme were able to be mobile along with their globally mobile parents, resulting in minimal detriment to their studies. The study also suggested that the IBD qualification was a versatile entry acceptable to many universities, as it was viewed as "a rigorous academic programme which facilitates international mobility" (Heyden & Wong, 1997).

2.2.2 Australian Curriculum Perspective on the International Baccalaureate

An initial literature search identified little formal material concerning the International Baccalaureate, other than the initial historical developments of the IBO (Peterson, 1972) and the gradual adoption of the International Baccalaureate Diploma (IBD) programme in the United States (Fox, 1985). Fox (1985) claimed that whilst the IBD curriculum was challenging and had rigor and academic strength he also claimed that it was also Euro-centric with elitist perceptions. It was considered that such comments may have reduced its appeal to the wider international market at that time.

In 1983 only one school in Australasia entered candidates for the IBD, as compared with 54 schools in Europe and 45 in North America. In 1972, two Australian students, attending the International School of Geneva, graduated the IBD and were accepted at the University of Sydney and Monash University in Melbourne. In 1979, the first Australian school, Narrabundah College in Canberra, offered the IBD programme to cater for the children of international diplomats. By 1992, 13 schools in Australia offered the IBD and an average of 75% of the participating students were Australian rather than international students. The majority of these schools adopted the IBD programme for its perceived benefits rather than dissatisfaction with the state or local curriculum (Bagnall, 1994).

Bagnall (1994) highlights two key issues that were encountered by these first Australian schools to offer the IBD programme. First, the IBD examination period was set in May to cater for Northern hemisphere schools, with a September to July academic year. As the number of schools offering the IBD in the southern hemisphere increased, the IBO initiated a second examination period in November to cater for the February to December school year. However, this new examination period only provided a limited selection of subjects. To manage the limited selection, some schools chose to utilise both examination sessions, May and November, giving students the opportunity to complete their local exams and a longer period to prepare for the IBD examinations. The benefits, however, were offset by a one year delay in students' tertiary entrance.

The second key issue outlined by Bagnall (1994) was the limited curriculum overlap between the local and IBD curriculum. To cope with small enrolments IBD physics students, for example, were often required to participate in local curriculum physics classes to reduce staffing costs. Unfortunately, because of the lack of similarity between the two syllabi, this is not ideal and was viewed as a major concern for the further adoption of the programme into Australian schools (Bagnall, 1994).

Of the thirteen schools that were offering the IBD in Australia in 1992, two were located in NSW. Both of the schools were independent and able to support the programme financially (Bagnall, 1994). Bagnall carried out a comprehensive survey of two of the 13 schools (neither of which were in NSW), and reported that 85% of the students felt that the IBD would help them in their choice of tertiary courses and that it was more challenging than the local course (Bagnall, 1994). Bagnall reported that students viewed the restriction of subject choice, heavily loaded programme (six compulsory academic subjects and core activities), difficult examinations and isolation from peers to be the greatest weakness of the IBD programme (loc. cit.).

During the final stages of completing this thesis a new Queensland University of Technology study of the IBD in Australia was published (Doherty, 2009; Doherty, Mu & Sheild. 2009). This new study draws on the literature cited here, but also investigated the positive nature of IBO marketing and the actual elements of choice offered to parents and students. These articles also emphasise the elite nature of the programme, the high fees, and concludes that the IBD is aimed at the 'cosmopolitan middle class' (Doherty, 2009, p.86). This larger study used a online survey to seek student opinion concerning their reasons for selecting the IBD and how it linked with their imagined future. Conclusions showed that the students envisaged flexible, internationally mobile futures (Doherty et al., 2009).

2.2.3 Comparing the IBD with other Curricula

Since its early developments, there have been few studies that compare the IBD with other curricula, particularly in the field of science education (Daniel & Cox, 1992; Hinrichs, 2003; National Research Council, 2002). This section summarises the findings of three studies in the U.S. which have compared the IBD programme with another curriculum to identify issues and trends that may be relevant to the current study.

In 1989 the Carnegie Council on Adolescent Development Report highlighted that, "American 13 year olds are now, on average, far behind their counterparts in other industrialised nations in mathematics and science achievement" (Carnegie Council on Adolescent Development Report, 1989, p. 27). The report went on to emphasise the importance of global citizenship and encouraging schools to adopt an ethos of personal responsibility for the well being of the world community.

In response to the report, Daniel and Cox (1992) carried out a study of education around the world to ascertain the opportunities available for talented students. They identified the IBO as an important contributor (Daniel & Cox, 1992). At this time the number of IBO member schools in the U.S. was were increasing rapidly, as the IB curriculum could be adopted whilst meeting state guidelines. Of the IBO schools in the U.S., 84% were independent schools all working alongside local curricula (Daniel & Cox, 1992). Issues related to this fact, according to Daniel and Cox (1992), arise largely as a result of the high cost involved with the application fee, annual fee, examination entry fees, new resources and staff development. IBD teaching staff identified issues related to the preparation time involved in tailoring material to meet the international dimension, and mastering new material, particularly in the Theory of Knowledge (TOK) unit. It was recognised that the rigour of the course meant that the IBD was only accessible to motivated learners; however both students' parents and teachers agreed that the challenge of educating for a better world as advocated by the IBO (International Baccalaureate Organisation, 2004) imparted a sense of mission and self respect. This was clearly one solution to the Carnegie Report, especially as the IBD includes a community action and global component to the programme (Daniel & Cox, 1992).

In 2000, the Centre for Education in the U.S. sought to compare the national secondary science programme, Advanced Placement, with the IBD programme (National Research Council, 2002). A panel of educationalists compared and evaluated each of the three sciences in the national Advanced Placement programme and the IBD programme, with respect to content, assessment and outcomes. This section reviews the findings related to Chemistry and Biology as these are pertinent to the present study. The panel was critical of deficits in both programmes. They advocated that programmes for advanced sciences should give students opportunities for the use of modern instrumentation, methods and information resources. In addition they recommended an extended use of inquiry based experimentation as well as the development of thinking skills and conceptual understanding. Both examinations systems were accused of not formally assessing laboratory skills, and being limited to predictable memory tests, rather than challenging a wider skill base. However, it was acknowledged that the internal assessment of practical work within the IBD was innovative and commended the data analysis question included on the external examination.

Although it was acknowledged that the Advanced Placement programme is a collection of unrelated courses, it was recommended that physics and mathematics be studied in parallel with chemistry. The National Research Council (2002) reported that, although the IBD subjects can be taken as stand-alone units, 65% of the IBD students work for and complete the requirements for the full diploma, which was recommended to provide a valuable, rounded educational experience.

Concern was raised over the lack of availability of well qualified chemistry teachers in the U.S. (National Research Council, 2002). As most secondary teachers were qualified in ‘science’, this is likely to provide breadth across biology, physics and chemistry, but not the depth. Also, most teachers with a science major had majored in biology, not the physical sciences (National Research Council, 2002).

In 2001, the Advanced Placement programme in the U.S. was again compared with the IBD programme with respect to international understanding (Hinrichs, 2003). Hinrichs (2003) states that science topics should include “…skill and understanding of the defining technologies of globalization: computerization, miniaturisation, digitisation, satellite communications, fibre optics, and the internet” (Hinrichs, 2003, p. 332). The results of the study indicated that IBD students did not differ significantly from Advanced Placement students in the area of technological development. However the results did find that IBD students had a significantly better concept of international understanding, demonstrated by a richness of vocabulary in their personal written definition of the terms (Hinrichs, 2003). The study reported in this thesis also considers the relative contribution of information and communication technologies (ICT) within the two programmes under study but with respect to science rather than specifically to globalisation.

A study of two schools in the U.S. that adopted the IBD as an alternative programme alongside the state curriculum is reported by Mathews and Hill (2005). In both of the schools, students were able to study either individual subject units or the whole IBD. The study reports several issues that were raised by the teachers and parents. Teachers viewed the IBO professional development as "annoyingly traditional" due to the didactic delivery and felt that the IBO did not value their expertise (Mathews & Hill, 2005, p. 57). Both the parents and teachers were concerned about the high cost of the programme as well as the growing view that the IBD programme was elitist with a Eurocentric focus. There was little information concerning the teaching and learning of science in these two schools, other than students' having difficulties with physics and struggling to attain good grades. Despite these issues, the study reports that the inclusion of the IBD raised the local status of the schools and improved enrolments (Mathews & Hill, 2005).

In summary, one of the main issues raised by the North American comparative studies was the high standard demanded of the IBD curriculum. This has presented challenges in terms of professional development and enrolment standards. Another key issue raised was the cost of implementing the curriculum with the high overheads and resourcing demands. Despite these issues, introducing the curriculum of the IBO was reported as being of benefit to all of the institutions studied.

2.3 CURRICULUM EVALUATION AND COMPARISON

The term curriculum originates from the Greek running tracks, where it literally meant a course. The Latin term *currere* means to run, which led to the word curriculum or racing chariot. John Franklin Bobbitt (1918) explains that, in the education context, the term curriculum is the course of deeds and experiences through which children become adults that are successful in society. In this sense, the curriculum encompasses the entire scope of formative experiences that occur in and out of school.

There are many definitions of educational curriculum, encompassing a range of ideas from the learning of set subjects in school (Wyndham, 1957) to the total educational experience of a student (Pinar, 1975; Taylor, 1971). Wojtczak, (2002, p. 2) defined curriculum as “an educational plan that spells out which goals and objectives should be achieved, which topics should be covered and which methods are to be used for learning, teaching and evaluation”. Coles (2003) distinguishes between syllabus and curriculum and explains that a list of topics is often referred to as a syllabus and that a curriculum should be a policy statement with advice as to how that is to be accomplished. According to Lovat & Smith (1995), a curriculum should include the informal, covert and overlooked aspects, often referred to as the hidden curriculum. Grundy (1987) argues that a curriculum is not concept but rather a cultural construction. It is observed that these definitions are products of their time and context; several imply that the curriculum is considered as an intention rather than an absolute, and that latterly the concept of what is included and excluded in the curriculum creates the experience or the ‘reality’ for the learner.

In formal education or schooling, the curriculum is generally viewed as the set of courses, course work, and content offered within an educational setting. Freebody (2003, p. 205) refers to these as “ruling texts and documents”. A curriculum may be partly or entirely determined by an external, authoritative body (such as the IBO). A curriculum can either refer to the range of courses from which students select the subject matters that they will study, or a specific learning program. In the case of a specific learning programme the curriculum collectively describes the teaching, learning, and assessment materials available for a given course of study. Crucial to the curriculum is the definition of the course objectives that usually are expressed as learning outcomes and normally include the program’s assessment strategies.

The syllabus, however, is generally a list of topics to be studied, following a traditional textbook approach in a logical order, with no indication of their relative importance. Focusing on the syllabus, as the main approach to curriculum, limits it to content alone and ignores the wider learning experience (Curzon, 1985).

It is with these perspectives in mind that the current study was undertaken. In this study, a basis for comparison was considered so that the same parameters are reviewed for both. To assess the success of a curriculum, a set of criteria or outcomes must be selected with levels of achievement set so that a judgement may be made as to its level of success. To examine models that could be used to guide the comparison of the two curricula (IBD and HSC), this section reviews the literature pertaining to educational models of curriculum evaluation (Section 2.3.1) and models that helped to focus the comparative analysis (Section 2.3.2).

2.3.1 Curriculum Evaluation

A range of definitions of curriculum evaluation were examined, including, the comparison of students' performance against certain standards, and describing and judging the curriculum. The definition selected to be most appropriate for use in this study is "using professional knowledge to judge the ongoing processes involved in the curriculum's implementation" (Brady, 1995, p. 246). This definition implies an ongoing evaluation process rather than a concluding step as in earlier definitions (Tyler, 1949; Wheeler, 1967). According to Lovat and Smith (1995, p. 164), the evaluation of a curriculum should be "at the heart of making choices", enabling informed decisions to be made.

A review of literature indicated that several models for evaluating curriculum have been developed since the middle of last century. This section describes six of these models including: Tyler's Objectives model; Wheeler's Rational model; Stake's Countenance Model; Stake's Responsive Model; Stake's Case Study Model; and Walberg's Model for Research on Instruction.

Tyler's Objectives Model

Tyler's (1949) Objectives Model was used in association with the development of new curricula. This model focuses on goals and involves the four basic steps of examining: objectives; content; method; and evaluation. This model is still being modified and, despite its age, is still relevant today. The International Association for the Evaluation of Educational Achievement (IEA) regularly conducts international comparative studies of schools using this model. Policy makers and educators have used the data collected by the IEA to: assess the impact of alternative curricula; monitor the quality of schooling worldwide; identify effective schools; and to learn how to improve their own educational systems. The IEA developed and implemented international test instruments, the main ones being the Third International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) which tested literacy, and what students can do with their knowledge (International Association for the Evaluation of Educational Achievement, 2004). However, it is widely recognised that outcomes alone do not provide a complete picture of the curriculum or of the teaching and learning processes involved.

Wheeler's Rational Model

Wheeler (1967) built on earlier models such as Tyler's Objectives model by separating the learning experiences of the students from the content of the curriculum. Five steps for action were identified: to specify aims and objectives; select experiences; select content; organise content and experiences; and, finally, to evaluate. These steps are represented in a circle which links back to the objectives. However, no clear definition of what makes up the content of the curriculum is given in this model.

Stake's Countenance Model

Stake has developed several models designed to evaluate the wider curriculum. He suggested preliminary activities to determine the goals of the evaluation rather than the straight collection of information. Stake's (1967) Countenance model comprises of two two-by-three matrices. The first is called the description matrix, and, working from the curriculum rationale, records the teacher's intent before, during and after an event. The event is then observed and recorded. The second matrix matches the recorded observations with the teacher's expected standards and, finally, judgements are made. Although this model has some capacity for reflection, it is still linear in process. Based on this original model, Stake developed two further models, the Responsive model and Case Study model – each of which are described below.

Stakes Responsive Model

Stake's responsive model (1976) emphasises the evaluation of educational issues, such as, discovering purposes and concerns, rather than objectives and participation in the curriculum. This approach is especially sensitive to identifying problem areas. It is flexible and uses the natural setting in which to conduct the evaluation. In this model Stake maps a linear series of twelve recommended steps as a guide to the evaluation process. Stake's Responsive model commences with identifying the scope of the programme to be evaluation (Step 1) then overviews the programme's activities (Step 2) and the purpose of the programme (Step 3). At this point the issues or problems are identified (Step 4) and decisions are made about the types of data required to examine the issue (Step 5) as well as decisions about the observers, judges and instruments required (Step 6). The next step involves observing designated antecedents, transactions and outcomes (Step 7). Evaluation then involves drawing out themes, preparing portrayals and case studies (Step 8), matching the issues to the audience (Step 9) and formatting the report to suit the audience (Step 10) and formal reports, if any, are then assembled (Step 11). Finally, the evaluation involves discussing the results with clients, programme staff and audiences (Step 12).

The Responsive Model was further developed when Stake encouraged evaluators to be even more responsive as they focused on issues that arose during the process of evaluating the curriculum.

Stake's Case Study Model

As a result of yet deeper research into curriculum evaluation, Stake (1978) developed a Case Study model that could be applied to particular situations. Some main features of this model included the fact that descriptions may be comprised of many variables which cannot be isolated. As such, data may emerge from personal observations and comparisons may be implicit rather than explicit. To this end, generalisations can be the product of the evaluators' experience and can include informal reporting. Stake's Case Study model has been criticised for subjectivity and generalisation, but can be appropriate for informing non-experts. It is important that consistencies amongst the aims, intended processes and expected outcomes are determined; and also congruencies amongst the actual processes and outcomes are recognised. The main advantages of this model are that the views and values of all the participants are considered and the evaluation can be responsive to the needs of the audience. The present study draws on this model during the evaluation process.

Walberg's Model for Research on Instruction

Walberg's model for research on instruction was developed from an assertion that three main classes of variables that influenced curriculum effectiveness included instruction, student aptitudes and learning environments (Walberg, 1970). He represented this relationship mathematically to demonstrate the interdependency of the variables. Walberg identified the strong influence of learning environments on student achievements and suggested that part of the role of the evaluator is to determine whether the curriculum changes the learning environment. His model promoted that students' learning should not only be examined as it is taking place, but also that the process and context of the learning experience be analysed. These ideas were drawn on to assist the evaluation and comparison of the two programmes in the current study.

The present study drew on Stake's Responsive Model and Case Study model, and Walberg's model for Research on Instruction to help to guide and frame the research. The Responsive Model was used to help to give structure to decisions related to the formulation of research questions, choice of data collection methods and the analyses of the data. Stake's (1978) Case Study model is an extension of his earlier Responsive model and was also considered pertinent to the present study. The model places an emphasis on the specific situation to be studied (in this case, the introduction of the IBD programme at Blackwood School) and the importance of the contextual effects on behaviour and the value of informal observations. Walberg's Model for Research on Instruction was also of interest to this study as it supports the importance of the aptitude of the student, the learning environment and also the instruction that surrounds the learning and teaching experience of the participants within the case study of the two parallel curricula.

2.3.2 Curriculum Comparison

In recent years, considerable research has been carried out to compare senior school curricula, both internationally and in Australia (Gilbert, 2004; Halls, 1971; Keeves, 2004; Rennie, Fraser & Treagust, 1999). The aim of the senior school curriculum, in the developed world, is to prepare students for life after school, including academic studies at a university, vocational studies at a training college and the workplace (Gilbert, 2004).

Because my review of literature revealed that, to date, there are few comparative studies that include the science curricula, general models for curriculum comparison were sought. This section describes two models that were considered suitable for use in the present study: a model for international curriculum comparison developed by Halls (1971); and a national Australian model (Australian Council for Educational Research, 2001) that focuses on skills.

An International Model of Curriculum Comparison

In 1964, the thirteenth General Conference of United Nations Educational, Scientific and Cultural Organisation sought to accelerate the social and economic progress of member countries by promoting international cooperation for the development of tertiary education. At this time, Halls (1971) designed a model for comparing the programmes of senior secondary schools around the world. The model examined the comparability and equivalence of secondary school certificates, tertiary entrance requirements and university degree programmes in different countries. The ensuing study intended to provide the evidence that could be used to facilitate the exchange of students undertaking either courses or research in their own country or overseas (Halls, 1971).

Halls analysed the current methods of comparing courses, programmes and curricula to help establish agreements on equivalence in access to higher education. He then designed a model for comparing the programmes of different senior secondary schools that could be used to establish the degree of pedagogical comparability between them. To this end he suggested that the subject content, objectives of the curriculum and the final leaving examination should be analysed and compared using an instrument of key items. Halls (1971) stated that it may not be possible to obtain perfect congruence, but if the plan to draw up profiles of a country's course, syllabuses, curricula and examinations using firm evidence was implemented, then recommendations for the mutual recognition of qualifications could be made.

This model was considered to be ideal for the present study. Halls provides examples of how the model can be used to examine experimental science and physics (the specialist subject of the researcher). Given the dynamic nature of physics, and the need to maintain a steady mass of content knowledge, more traditional topics have to be periodically replaced to accommodate current theories, discoveries and innovation. Therefore, an updated model, based on Halls' (1971) model, was developed for the purposes of this study. Section 3.4.1 provides details of the model, the adaptations made to make it suitable for the present study, and an explanation of how the model was used to compare the IBD and HSC curriculum.

Australian Models of Curriculum Comparison

A shift in emphasis from content to process in science curricula emerged from reform movements in the United States during the 1990s (Keeves, 2004; Rennie Fraser & Treagust, 1999). To accommodate these changes in emphasis the Australian Council for Educational Research (ACER) identified a framework of generic skills within an assessment framework model (Australian Council for Educational Research, 2001). Australian Council for Educational Research's framework goes beyond what are technically known as skills, to include predispositions such as scepticism, tolerance and commitment. The development of these predispositions, (the metacognitive skills), was considered to be important to help students to construct their own knowledge or content base, and to provide for themselves a more engaging context for learning. These skills were considered crucial for the transferability of knowledge and skills from the classroom to the wider world and had particular significance for the preparation of life-long learning (Bryce, Frigo, McKenzie & Withers, 2000).

The comprehensive list of generic skills developed by Australian Council for Educational Research (2001) formed an integral part of the development of curricula in Queensland. A curriculum comparison between all of the curriculum documents in Queensland was conducted as part of the Queensland Studies Authority Review of the Senior Phase of Schooling (Gilbert, 2004). The project aimed to assess the extent to which syllabus documents in Queensland provided courses of study that would prepare students for a range of destinations. A composite framework, incorporating the Australian Council for Educational Research (2001) skills framework model, was used. Gilbert examined the intended learning outcomes and the subject area specifications of twenty-three subjects, included biology, chemistry and physics (Gilbert, 2004). Documents were analysed by the frequency with which each skill was mentioned. According to Gilbert (2004) the frequency with which a skill is mentioned has two implications, first, the frequency helps to determine whether and to what extent the outcome appears at all and, second, the number of mentions indicates the relative importance attributed to the outcome.

The results of the analysis of the Queensland syllabus documents indicate that the syllabi gave varied attention to all skills except deep learning and knowledge. The analysing and synthesising for problem solving skills and using evidence and argument skills, were seen as important intended outcomes in most of the documents. Metacognitive skills, however, were not mentioned at all. In summary, Gilbert (2004) reported that the Queensland syllabi offer students a vast variety of learning options within their subject choice.

The two models reported in this section, were used to provide an in-depth comparative analysis of the two science programmes in the current study. Halls' model was adapted to meet recent advances in science that are included in today's curricula used to help compare the respective syllabus documents (Halls, 1971). The Australian Council for Educational Research model (Gilbert, 2004) was used to help to focus on and compare the skills embedded in each of the syllabi. The results of the comparative analyses of the intended curriculum can be found in Chapter 4.

2.4 STUDY OF LEARNING ENVIRONMENTS

According to Walberg (1970), a student's experience of the curriculum can be substantially influenced by their learning environment. The present study draws on the field of learning environments to help examine the experience of the students studying within the IBD and HSC programmes. Section 2.4.1 investigates the historical background behind research in this area and the development of instruments over the past 30 years with which to measure students' experience of the learning environment. Section 2.4.2 examines the extensive application of these instruments internationally and their modifications. Section 2.4.3 describes the development, use and validity of the Science Laboratory Environment Inventory (SLEI) that was used in the present study.

2.4.1 Historical Background

Because this research draws on the field of learning environments, this section reviews some of the literature related to this field. Past work on learning environments has provided conceptual models, research traditions, assessment techniques and research methods that are relevant to this study.

Research within the field of learning environments is based upon the earlier ideas of Kurt Lewin (1936) and H.A. Murray (1938). In 1936, Lewin proposed that both learning environment and its interaction with personal characteristics of an individual are powerful determinants of human behaviour. He introduced what is known as the Lewinian formula, $B=f$ (P, E), to describe human behaviour (B) as the result of two influences that are interdependent, the person (P) and the environment (E).
Following Lewin's idea, Murray proposed a needs-press model of interaction, in which personal needs represent the tendency of individuals to move in the direction of goals and the environmental press is the external situational counterpart that either supports of frustrates the expression of those needs. Murray also referred to the terms alpha press and beta press to distinguish between the environment which is observed by the external observer, to the one that perceived by the inhabitant, respectively. Murray's need-press model was further developed and made popular by Pace and Stern (1958), who distinguished between the view that each person has of the environment or the private alpha press and the shared view that a group has about the environment or the consensual beta press.

In 1981, Walberg proposed a nine-factor model of educational productivity (Walberg, 1981). The model proposes that student outcomes are determined by the interaction of three student aptitude variables, these being the quantity and quality of instruction, and the psychosocial environments of the school/class, the home, the peer group, and the mass media (Fraser, Walberg, Welch & Hattie, 1987; Walberg, 1986). According to Walberg, the improvement of student achievement is unlikely to occur unless several factors are aligned and raised simultaneously and that the improvement of a single factor is unlikely to have a large impact on student achievement. There have been some empirical probes of the educational productivity model, involving the syntheses of past research and including correlations between student outcomes and the factors in the model (Fraser Walberg, Welch & Hattie, 1987; Walberg, 1986). A secondary analysis of large data bases collected as part of the National Assessment of Educational Achievement (Walberg, 1986) and National Assessment of Educational Progress (Walberg, Fraser & Welch, 1986) found classroom and school environment to be strong predictors of both achievement and attitudes even when a comprehensive set of other factors was held constant.

Herbert Walberg and Rudolf Moos independently pioneered the use of perceptual measures to assess the learning environment almost four decades ago. Research and evaluation related to Harvard Project Physics led Walberg and Anderson (1968) to develop the Learning Environment Inventory (LEI). Moos (1974) developed a scheme for classifying human environments into three dimensions (relationship, personal development, and system maintenance and change) to enable the classification and sorting of various components of any human environment. This led Moos to the development of the Classroom Environment Scale (CES; Moos, 1974; Moos & Trickett, 1987), which was linked to his work in other human environments including hospitals and prisons.

Following the pioneering research of Walberg and Moos in the US, two further programs of learning environment research emerged, one in the Netherlands and one in Australia. In the Netherlands, research focused on the interaction between teachers and students in the classroom and involved the use of the Questionnaire on Teacher Interaction (QTI; Fraser & Walberg, 2005; Wubbels & Brekelmans, 1998; Wubbels & Levy, 1993). In Australia, research was focused initially on student-centred classrooms and involved use of the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990). Since that time, other instruments have been developed in Australia and cross-validated and applied for a variety of research purposes. In particular, these questionnaires include the Constructivist Learning Environment Survey (CLES; Kim, Fisher & Fraser, 1999; Nix, Fraser & Ledbetter, 2005; Spinner & Fraser, 2005; Taylor, Fraser & Fisher, 1997), the What Is Happening In this Class? (WIHIC; Aldridge, Fraser & Huang, 1999; Chionh &

Fraser, 2009; Dorman, 2003; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008) and the Science Laboratory Environment Inventory (SLEI; Fraser, Giddings & McRobbie, 1995; Henderson, Fisher & Fraser, 2000; Lightburn & Fraser, 2007; Wong & Fraser, 1996).

2.4.2 Applications of Classroom Environment Instruments

Over the past 30 years there have been numerous classroom environment studies conducted around the world with a variety of purposes (Fisher & Khine, 2006; Fraser, 1998a, 1998b, 2007; Goh & Khine, 2002). One of the strongest themes in past classroom learning environment research has involved investigations into associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classroom environments (Fraser & Fisher, 1982; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). Numerous studies have shown students' perceptions of their classroom environments, relative to students' background characteristics, to be closely associated with their learning outcomes.

Learning environment instruments have been used successfully in identifying the differences in perception of the classroom environment between students and their teachers (Fisher & Fraser, 1983), identifying exemplary teachers (Waldrip, Fisher & Dorman, 2009) and guiding teacher's decisions about implementing strategies to change students' perceptions (Sebela, Aldridge & Fraser, 2004; Waldrip, Reene, Fisher & Dorman, 2008). Other factors affecting the success of the classroom environment have also been identified by using learning environment instruments. These factors include cultural differences, depending upon the race of the teacher in Brunei (Khine & Fisher, 2002); in Korea the focus of the class group was investigated, whether students were science or humanities orientated (Lee, Fraser & Fisher, 2003); and the observation of the factor of gender difference across several countries (Chionh & Fraser, 2009; Quek, Wong & Fraser, 2005). Large cross-national studies have also been carried out for the purpose of gaining new insights into such areas as teaching methods and student attitudes that might be overlooked within one culture (Aldridge, Fraser, Taylor & Chen, 2000)

Another application of learning questionnaires in past research has been as a source of process criteria of effectiveness in curriculum evaluation. This is because they have differentiated revealingly between alternative curricula when student outcome measures have shown little sensitivity (Fraser, Williamson & Tobin, 1987). In addition, classroom environment instruments have been used for the evaluation of educational innovations in Australia, such as the Australian Science Education Project (ASEP; Fraser, 1979) and more recently in an outcomes-focused, technology-rich school (Aldridge & Fraser, 2008). Overseas the use of learning environment criteria has illuminated the impact of a wide range of new educational programs or approaches. These include computer-assisted learning in Singapore (Maor & Fraser, 1996; Teh & Fraser, 1994) and Canada (Raaflaub & Fraser, 2002), computer courses for adults (Khoo & Fraser, 2008); innovations with anthropometry activities in science education was evaluated in the US (Lightburn & Fraser, 2007); Year 11 earth science in Korea (Oh & Yager, 2004), inquiry-based science instruction for middle-school students (Wolf & Fraser, 2008), an innovative science course for prospective elementary students (Martin-Dunlop & Fraser, 2008) and the effectiveness of the Science and Mathematics Integrated with Literary Experiences (SMILE) project carried out with fifth grade students in the United States (Mink & Fraser, 2005).

The results of the Australian Science Education Project study (Fraser, 1979) revealed that, when compared with a control group, students perceived their classrooms as being more satisfying and individualised and as having a better material environment. This research is significant because it demonstrated that learning environment criteria were able to differentiate between curricula, even when various outcome measures showed negligible differences (Fraser, 2007). One of the objectives of the present study was to evaluate and compare the IBD and HSC science programmes in terms of the learning environment created in the science laboratories.

2.4.3 Science Laboratory Environment Inventory (SLEI)

Within science-related disciplines, the learning environment of laboratory settings is especially important (Hofstein & Lunetta, 1982, 2004). To investigate whether the two curricula differed in terms of the learning environment, the Science Laboratory Learning Inventory was used in the present study.

The Science Laboratory Environment Inventory (SLEI) was developed by Fraser, Giddings and McRobbie (1995) to assess dimensions that relate specifically to the learning environment of science laboratory classes, namely Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. For example, Open-endedness pertains to the extent to which the laboratory activities emphasise on open-ended divergent approach to experimentation. In other words, is there a choice as to how things are done to explore problems for which the answer is not already known? Integration refers to the extent to which laboratory activities are integrated with non-laboratory and theory classes. That is, does what is being taught in the lecture support what is being tested in the laboratory? Table 2.1 provides a description of each scale as well as a sample item.

Table 2.1: Descriptive Information for Each Scale of the SLEI

Scale Name	Description	Sample Item
	The extent to which	
Student Cohesiveness	… students know, help and support each other.	I get along well with students in this laboratory class. (+)
Open-endedness	… the laboratory activities emphasise an open-ended divergent approach to experimentation.	In my laboratory sessions, the teacher decides the best way for me to carry out the experiments. (-)
Integration	… the laboratory activities are integrated with non-laboratory and theory classes.	I use the theory from my regular science class sessions during laboratory sessions. (+)
Rule Clarity	… behaviour in the laboratory is guided by formal rules.	There is a recognised way for me to do things safely in this laboratory. (+)
Material Environment	… the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

Items designated (+) are scored 1, 2, 3, 4, and 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often, and Very Often.
Items designated (-) are scored 5, 4, 3, 2, and 1, respectively, for the response Almost Never, Seldom, Sometimes, Often, and Very Often

The initial version of the SLEI contained 72 items and eight scales, but extensive field testing and item and factor analysis led to a more valid and economical version. The final version has seven items in each of the five original scales, giving a total of

35 items which are responded to using a five-point frequency response scale of Almost Never, Seldom, Sometimes, Often and Almost Always.

The SLEI has been used and validated in six countries, including Australia, (Fisher, Harrison, Henderson & Hofstein, 1998; Fraser, & McRobbie, 1995; Henderson, Fisher & Fraser, 2000), Israel (Cohen & Lazarowitz, 1996; Hofstein, 2006), Singapore (Quek, Wong & Fraser, 2005), Korea (Lee, Fraser & Fisher, 2003), Brunei (Riah & Fraser, 1998) and Nigeria (Aladejana & Aderibige, 2007). Of interest were those studies carried out in Australia that provide information about the reliability and validity of the SLEI.

Several Australian studies have provided information about the reliability of the SLEI. One study cross-validated the SLEI with 1594 students and found the instrument to have strong factorial validity (Fraser & McRobbie, 1995). Two further studies in Australia, one involving 489 biology students (Henderson, Fisher & Fraser, 2000) and another involving 400 senior science students (Fisher, Harrison, Henderson & Hofstein, 1998) provide strong evidence for the reliability and validity of the SLEI.

The SLEI has been used to examine relationships between students' perceptions of their science laboratory environment and their attitudinal and achievement outcomes (Aladejana & Aderibigbe, 2007; Henderson, Fisher & Fraser, 2000; Quek, Wong & Fraser, 2005). In each case, positive correlations between student outcomes and scales of the SLEI were found. The SLEI has also been used to investigate differences between the laboratory environment of different science subjects (Fisher, Harrison, Henderson & Hofstein, 1998; Hofstein, Cohen & Lazarowitz, 1996). An Australian study, involving 400 students, examined whether the laboratory environments differed for biology, chemistry and physics classes. The results indicated that differences in the laboratory teaching of the three curricula could be clearly identified by using the instrument (Fisher, Harrison, Henderson & Hofstein, 1998). In Israel, similar results were found when chemistry and biology laboratory environments were compared.

A review of literature indicates that the SLEI has been extensively validated in past studies both overseas and in Australia. In addition, past studies provide support for the ability of the SLEI to identify differences in the laboratory learning environment of different curricula. As such, it was considered suitable for use in the present study to identify the students' perceptions of the science laboratory learning environment in the IBD and HSC programmes.

2.5 MULTIPLE INTELLIGENCE THEORY, LEARNING STYLES AND CAREER CHOICE

Internationally, in developed countries, there has been a steady decline in the number of students choosing to study science subjects, particularly physics (National Science Foundation, 2004; European Commission, 2004; Organisation for Economic Cooperation and Development, 2005; Board of Studies, 2007). Consequently there is also a decline in the number of students choosing science degree or careers paths. Recent research into learning styles has indicated that a student's individual learning styles could be a contributory factor in learning science. If teaching and learning styles are addressed to make the subject more accessible, this could impact on career choice (Chapman, 2003; Kornhaber, 2004).

This section reviews literature related to learning theory, multiple intelligences, learning styles and how these might be related to career choice. Section 2.5.1 investigates the historical background behind this learning theory, followed by recent applications in Section 2.5.2. Section 2.5.3 previews the Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA) which is of interest to this study.

2.5.1 Historical Background

A traditional model of intelligence, understood by educationalists and psychologists, was that a single underlying characteristic is responsible for differences in a person's reasoning and learning. Standard Intelligence Quota tests were established to classify this ability. This numerical value was a theoretical construct assigned to produce data regarding a person's behaviour and performance on specific tasks. Research carried out more recently has challenged this theoretical concept as setting artificial limitations on the understanding of intelligence. The single entity of intelligence quotient has since been expanded to include a range of mental abilities.

In 1983, Gardner, proposed that there were multiple intelligences underpinning human thinking and learning (Gardner, 1993). He suggested that there was a strong heritability factor and emphasised the importance of both educational and cultural factors in influencing people's function in each of the intelligences (Project Zero, nd; McGrath & Noble, 2005). Gardner identified first seven and later eight intelligences in his theory of Multiple Intelligences (MI), these being: verbal-linguistic intelligence, logical-mathematical intelligence, visual-spatial intelligence, bodily-kinaesthetic intelligence, musical intelligence, interpersonal intelligence, intrapersonal intelligence and naturalist intelligence. More recently Gardner has suggested three further possible intelligences, these being existential intelligence, emotional intelligences and digital intelligence (Gardner, 2003).

Gardner's theory was not generally accepted within academic psychology. For example Klein (2003) agrees that whilst claims are true for students to demonstrate a variety of strengths, and this has been overlooked in traditional education, these strengths are not primarily explained by the construct of intelligence. He purports that MI theory is only one way of constructing a relationship between the curriculum and a student's cognitive resources (Klein, 2003). However, MI theory was met with a positive response from many teachers and education policy makers who, in agreement with Klein (2003), viewed Gardner's theory as an approach that would enable issues within teaching and learning to be addressed. Twenty years later, his theory has been supported by advances in electrophysiological studies, neural imaging and the identification of genes contributing to intelligence quotient (Gardner, 2004).

2.5.2 Applications of the Multiple Intelligences Theory

Each of the eight original intelligences includes different clusters of skills, and it is suggested that environments may influence the development of some skills more than others, or cause them to be expressed differently in other contexts (McGrath &

Noble, 2005). Although everyone possesses all eight intelligences, most people exhibit a range of strengths that form a personal profile. It is suggested that these relative differences can impact on a person's interests and career choices (Chapman, 2003; Kallenbach & Viens, 2002). For example, strength in logical-mathematical intelligence, linked to an ability to detect patterns, scientific reasoning and deduction could increase the likelihood of success in this area and lead a student towards a science orientated career.

Gardner, supported by his case studies, purported that translating his MI theory into a practical situation:

> …allows individuals (particularly parents and teachers) in a non-threatening way to look more carefully at children, to examine their own assumptions about potential and achievement, to consider a variety of approaches to teaching, to try out alternative forms of assessment – in short, to begin the fundamental kind of self-transformation that is necessary if schooling is to improve significantly (Gardner, 1993, p. 5).

As part of Harvard Project Zero and Project Spectrum, Gardner (2003) and his team sought to create a set of measures by which the different intelligences of young children could be ascertained. In 1992, Project Zero launched an initial study into the MI theory. Interviews were carried out with principals from eleven U.S. schools who used the MI theory to develop their curriculum. It was found that, by incorporating MI theory into the curriculum design, there were a number of benefits, including: a new vocabulary for teachers to use when discussing children's strengths; validating the practices of teachers whose work was already aligned with MI theory; promoting the delivery of the curriculum in diverse forms; and encouraging teamwork between teachers. These benefits have been supported by more recent studies (Project Zero, nd; Goodnough, 2001).

From this initial Harvard Project Zero stemmed Project SUMIT (Schools Using Multiple Intelligence Theory), which ran from 1997-2000 and investigated 40 schools in the US that were implementing MI theory. The aim of this project was to identify, document and then promote successful applications of MI theory, associated with improvement in student achievement in test scores, work quality, attendance and behaviour (Kornhaber, 2004).

In 1999, Campbell and Campbell (1999) studied two U.S. high schools that embraced Gardner's work, and adopted it as part of their school philosophy. These two schools both sought to motivate low achieving students and to cope with students from more diverse backgrounds. The results indicated that, as a result of this approach, attendance improved and scores increased to such an extent that both of the schools won awards and moved to the top of their district. Also, teachers reported that they had benefited from the teamwork, gained confidence alongside the students and learning had become accessible for all (Campbell & Campbell, 1999). These reports from Project Zero (nd) and Campbell and Campbell (1999) indicate that if MI theory is understood and implemented by teachers, then student achievement and motivation may be increased.

Past studies have indicated that by information collected by administering an MI instrument to students can help to ascertain students preferred learning styles. This enables students to gain insight into their personal strengths and informs teachers in ways that enable them to tailor their delivery styles and assessments to better match the needs of their students (Thompson & McDougall, 2002). Such information may also give insights into degree programmes and careers that are most suitable for the students (Chapman, 2003).
The Adult Multiple Intelligences Study (AMI) was developed to promote the application of MI theory within adult literacy education through the production of suitable resources (Kallenbach & Viens, 2002). This small study found the application of the MI theory to be successful with adult students and can have a powerful impact on student's career plans (Kallenbach & Viens, 2002). The majority of these studies have been carried out with small groups and primary and middle school children, with the exception of the AMI Study which was carried out with adults. Research findings indicated that translating the MI theory into practice can have positive outcomes in improving test scores, behaviour and parent participation (Kornhaber, 2004).

2.5.3 Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA)

Prior to the commencement of the present study, I attended a professional development session during which I was introduced to the Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA) instrument, which led to its inclusion in the study. Although other MI instruments were examined, such as the AMI test (Kallenbach & Viens, 2002), these were considered to be unsuitable for the purpose of this study.

The Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA) instrument is a self-report measure that requires students to rate themselves on statements of perceived competencies, according to Gardner's eight intelligences (McGrath & Noble, 2005). For each of Gardner's eight intelligences, seven descriptive statements are provided to which students respond to according to three choices ('Very True of Me' – which scores 3; 'Somewhat True of Me' – which scores 2; and 'Not True of Me' – which scores 1).

To ensure the usefulness of the MICA at the high school level, terms were simplified so that they were meaningful and more easily understood by students. Table 2.2 lists each of Gardner's eight intelligences. In the adjacent column the simplified term is listed, for example, 'verbal-linguistic intelligence' was changed to 'word intelligence'. Finally, the right hand column links each of the eight intelligences with abilities that a student with that intelligence might exhibit. Figure 2.1 provides an example item of a typical question used to demonstrate an ability indicated by an intelligence type, in this example Word intelligence is used. Also included in the figure is the score range by which the student records how the statement applies to herself. When students respond to the MICA they write their score next to each question number.

Table 2.2: Clarification of Gardner's Multiple Intelligences related to the MICA study

Gardner Terms	MICA Study Terms	Ability with
Verbal-linguistic intelligence	Word intelligence	… retention, interpretation and explanation of ideas and information via language,
Logical-mathematical intelligence	Logic and mathematical intelligence	… detecting patterns, scientific reasoning and deduction; analyse problems, perform mathematical calculations,
Visual-spatial intelligence	Space and vision intelligence	… interpretation and creation of visual images; understands relationship between images and meanings
Bodily-kinaesthetic intelligence	Body intelligence	… body movement control, manual dexterity, physical agility
Musical intelligence	Music intelligence	… awareness, appreciation and use of sound
Interpersonal intelligence	People intelligence	… relating to others; interpretation of behaviour and communications
Intrapersonal intelligence	Self intelligence	… self-awareness, personal cognisance, personal objectivity
Naturalist intelligence	Naturalist intelligence	… noticing characteristics of natural things and categorising them; involves keen observation

Adapted from McGrath & Noble, 2005

Intelligence	Statement	Response		
		Very True	Somewhat True	Not True
Word Intelligence	I write well and can usually find the right words to say what I mean and to communicate my ideas.	3	2	1

Figure 2.1: Illustration of the layout of MICA statement and response format.

Once the questionnaire is completed, the total score for each of the intelligence scales is calculated and ranked from highest to lowest. The magnitude of the score indicates the strength of the student's ability in that intelligence. Exhibiting strength, or a high score, in an area of intelligence indicates a person's innate ability within this area of skill and understanding. This ability has been linked to providing a gauge of their preferred learning styles and to career pathways (Chapman, 2003; Kallenbach & Viens, 2002). Appendix B provides a copy of the MICA as used in the present study.

An Australian study by Perry and Ball (2004), explored the individual differences displayed by students. This study used the MICA, along with two other instruments, with 336 teacher education students, 86 of whom were specialising in science and mathematics. The results showed that of the 336 students, the science and mathematics group recorded the highest scores for Logical-Mathematical Intelligence ($p<0.0001$) and for Spatial Intelligence ($p<0.01$). They also scored highly for the Interpersonal Intelligence, indicating a preference for team work (Perry & Ball, 2004). The Naturalist Intelligence had not been incorporated into the MICA at this stage.

Using the sample of 336 students, Perry and Ball (2004) reported that the reliability estimates for each MICA scale raged between 0.62 and 0.81. Although the study provided evidence of psychometric quality in terms of scale reliability, it is acknowledged that the unidimensionality of the MICA was not indicated.

The purpose of administering the MICA as part of the present study was two-fold. First, the information could help the science teachers to understand the importance in varying their teaching styles and approaches to learning to accommodate all students (Thompson & MacDougall, 2002). Second, because science was compulsory in the IBD and optional in the HSC, it was useful to investigate whether one curriculum might attract students with a different intelligence than the other, thereby influencing the type of career path a student might follow. The MICA was used to provide an indication of whether this was the case.

2.6 CHAPTER SUMMARY

This chapter reviews a range of the literature relevant to the present study. Initially a suitable definition of curriculum was sought. The definition chosen for this study was that of Wojtczak (2002, p. 2), “an educational plan that spells out which goals and objectives should be achieved, which topics should be covered and which methods are to be used for learning, teaching and evaluation”.

To provide a context within which to apply the definition of curriculum, the recent background history of science education is reviewed. This section highlights the international decline of students both studying science and moving into scientific careers and the concerns of both educators and governments (Australian Council for Deans of Science, 2004; Butler, 2008; Walker, 2005). In an attempt to remedy this, science curricula world-wide is undergoing reform.

Recent curriculum reforms in science education have attempted to both improve scientific literacy, knowledge of applications and to make science generally more accessible (Australian Council for Educational Research, 2001; Conley, 2003). International testing has been introduced in the form of PISA and TIMSS in an attempt to judge the success of the implemented curriculum (Organisation for Economic Cooperation and Development, 2005). Wallace and Louden (1998), however, identified that, not only strategies and resources but the input of teachers and students is important in the implementation of curriculum change.

A further implication in the movement of students away form science is the decline in students following scientific careers. This again is an international problem due to the poor image of scientists (Woolnough, 1996; European Commissions, 2004; Schreiner & Sjøberg, 2007). A review of research that investigated students' perspective of their science curriculum revealed that, internationally, projects draw remarkably similar conclusions. Students in developed countries are generally disengaged with school science and do not perceive its relevance to their teenage lives (Curtis, 2002; Schreiner & Sjøberg, 2007). A review of research related to the choices students make with regards to senior science subject selection and careers in science fields was made. The review highlights the importance of the perceived relevance and enjoyment of the science curriculum prior to the selection process, and the necessity of good science career advice.

The new curriculum, being introduced at the Blackwood School, is the International Baccalaureate Diploma (IBD). Literature related to the International Baccalaureate Organisation (IBO) was not easily sourced. The historical perspective is summarised from a book written by the first IBO Director General (Peterson, 1972).

The first Australian school to join the IBO was in 1979 (Bagnall, 1994). In 1994 Bagnall's study provided insights into issues related to introducing the IBD but did not involve science subjects (Bagnall, 1994). More recently, studies in the U.S. have compared the IBD with the national curriculum, predominantly. (Daniel & Cox, 1992; Hinrichs, 2003; Mathews & Hill, 2005; National Research Council, 2002). Again little has been reported in the field of science but some of the general issues raised concern the elitism of the IBD, cost and academic rigor. A comparative study involving the IBD and science students took place with Finnish and Portuguese students (James, 2007). This study examined reasons behind a student's choice of subject and provided a useful basis for comparison with the findings of the present study.

Because the evaluation of the IBD and HSC was an important component of the present study, definitions of curriculum evaluation were sought, and various models of curriculum evaluation were reviewed (Hammond, 1973, Organisation for Economic Cooperation and Development, 2005; Stake, 1967, 1976, 1978; Tyler, 1949; Walberg, 1970). These models were reviewed in the light of the study context, and three models, Stake (1976, 1978) and Walberg (1975), were used to help guide the present study. Stake's Responsive model, combined with his Case Study model provided a suitable evaluative process framework within the context of the senior school, whilst Walberg's concern for the learning environment was considered to be particularly suitable for the discipline of science.

Studies that have compared curricula, both internationally and in Australia, were reviewed (Gilbert, 2004; Halls, 1971; Keeves, 2004; Rennie, Fraser & Treagust, 1999). For the purpose of this study, models were sought to help to compare the two curricula under investigation. Keeve's model (2004) was used to contextualise the two curricula. Only limited literature was available with a specific science perspective, however, Halls (1971) compared the science curricula of six countries. For the purposes of this study, Halls' model was drawn on to help to compare the two curricula being delivered at Blackwood School. To help compare the skills taught in each of the science programmes, Gilbert's (2004) model was used. Gilbert's model was based on the Australian Council for Educational Research, (2001) skills framework which identifies eighteen generic skills categories that can be applied to examine a school curriculum.

To examine the learning environment created within the two different curricula, literature related to the field of learning environment was reviewed. The field has established a wide range of research over the past 30 years with an international reputation (Fraser, 2007). The review indicates that a wide range of instruments are available that have been validated in a variety of subjects and year levels. The Science Laboratory Environment Inventory (SLEI) (Fraser, Giddings & McRobbie, 1995) was selected for use in the present study. The relevance and appropriateness of the level of questions, the ease with which it can be administered and the simplicity of the scoring mechanism are ideal for contributing to the evaluation of the wider curriculum (Fraser, Giddings & McRobbie, 1995). Furthermore, the SLEI has been validated with students in Australia and overseas (Fisher, Harrison, Henderson & Hofstein, 1998; Henderson, Fisher & Fraser, 2000; Hofstein, 2006; Lee, Fraser & Fisher, 2003; Quek, Wong & Fraser, 2005) making it suitable for use with the small sample included in the present study.

Literature pertinent to the theory of multiple intelligence and the individual learning styles of students was reviewed. Of particular interest were those factors which might impact on a student's choice of subject and subsequently their career. Literature related to the work of Gardner (McGrath & Noble, 2005) and his theory of Multiple Intelligences (MI) was reviewed. Gardner (2003) proposed that there were eight intelligences underpinning human thinking and learning which dictate our learning styles and preferences. The Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA) instrument (McGrath & Noble, 2005) was selected to explore this area within the current study because of its suitability for use at the high school level.

This chapter has provided background of current educational research on the breadth of curriculum definition, comparison and evaluation. It has revealed the relative lack of information available in the area of the IBD, particularly science education. Further, it exposes serious issues in the quality and delivery of current science curricula internationally and its failure to engage high school students. The review also provides models that were used on the present study. The next chapter provides details of the research methods used in the present study.

CHAPTER 3

RESEARCH METHODS

Chapter 2 highlighted how this study draws on and builds upon research from different fields to examine the teaching and learning of science within the IBD programme at Blackwood School and to compare it to that of the local HSC science programme that was running concurrently at the school. This two-year longitudinal study coincided with the introduction and commencement of the IBD programme. The study made use of a multi-method approach to address specific research objectives to review and evaluate the delivery of science within the two programmes. This chapter describes the research methods selected to generate information used to answer each of the research objectives. Details of the procedures used for the collection of data and the instruments used are organised under the following headings:

3.1 Research Objectives;
3.2 Theoretical Framework;
3.3 Sample;
3.4 Research Methods;
3.5 Analyses of the Data;
3.6 Addressing Ethical Concerns; and
3.7 Chapter Summary.

3.1 RESEARCH OBJECTIVES

The first research objective was designed to provide an understanding and overview of the intended curricula.

Research Objective #1

> To investigate whether differences exist between the IBD science programme and the HSC science programme in terms of the curriculum content, objectives and assessment requirements.

The second and third objectives sought the views of the science teachers and the students participating in the two programmes to examine their perspectives of issues related to the implemented curricula.

Research Objective #2

> To examine teachers' views of the issues involved in the teaching, learning and assessment in the IBD and HSC programmes at the school.

Research Objective #3

> To investigate whether differences exist for students enrolled in HSC and IBD programmes in terms of students' views of the learning environment.

The fourth objective concerned a comparison of the achieved curricula.

Research Objective #4

> To examine whether the outcomes of students enrolled in the HSC and IBD science programmes differ in terms of:
>
> b) their propensity and desire to pursue a career in science;
>
> c) whether the science programme lived up to the expectations of the students; and
>
> d) student achievement according to the University Admissions Index.

The final objective sought the views of the science students participating in the two programmes with respect to their enjoyment of the Year 10 science programme and the preparation that it provided for their current studies.

Research Objective #5

> To investigate whether the Year 10 science programme provides an enjoyable experience and whether differences exist for students enrolled in IBD and HSC in terms of adequate preparation for their selected programme.

These objectives were addressed over a two year period, following the progress of the first cohort of students participating in the IBD programme and their HSC counterparts at Blackwood School.

3.2 THEORETICAL FRAMEWORK

The present study includes both qualitative and quantitative research methods, drawing on multiple research methods within an evaluation framework (Anderson, 1998). Both quantitative and qualitative methods were used in order to combine the strengths of each method and to counterbalance any weaknesses (Bryman, 1980; Denzin & Lincoln, 2005; Edwards &Talbot, 1994; Hakim, 2000). This combination of methodologies enables a more complete picture to be produced (Bryman, 1980) and assists in establishing ‘valid, reliable and robust conclusions to provide a firm basis for decisions.’ (Hakim, 2000, p. 173). This approach to research has been described by Denzin (1978) as triangulation by method, as a balance of strengths and weakness is achieved by taking different points of reference through the use of a variety of methods. This study used a combination of surveys and document analysis (quantitative) and focus group discussions, in-depth interviews and observations (qualitative) to supply data for triangulation (Denzin, 1978). Each of these specific methods is discussed in detail in subsequent sections of this chapter (Sections 3.4 and 3.5).

Evaluation research, according to Patton (2002, p. 218), tests the "effectiveness of specific solutions and human interventions" which, in this case, is the introduction of the IBD programme at Blackwood School. The evaluations made by the present study examine and judge the process and outcomes associated with the delivery of the new programme. This research aimed to provide information for two purposes, the first was to provide a formative evaluation that could be used to guide improvements in the delivery of the programmes at the school and the second was to provide a summative evaluation that could be used to inform decisions about whether the program could be usefully included as an alternative programme in other schools.

In this study I collected and made use of a variety of empirical materials including focus group interviews, in-depth interviews, observations, surveys and documents. According to Anderson (1998), review and evaluation is a good strategy to investigate whether a particular approach is the best way to achieve a desired result.

Lincoln and Guba have produced a helpful heuristic device, in the form of tables entitled "Basic Beliefs of Alternative Inquiry Paradigms" and "Paradigm Positions on Selected Issues" (Lincoln & Guba, 2000, pp. 168-171), that can be used to help track movement that I made between the paradigms of constructivism, postpositivism (critical realism) and participatory research.

As a physical scientist by education and training, I commenced the study with a more logical-positivist approach, in which I reviewed literature and sought instruments with which to collect data. I then shifted to the more interactive model of critical realism, in which I recognised "that all knowledge and values are created in social contexts" (Hugman, 2005, p. 133). As I was a senior teacher at Blackwood School, I was already involved with teaching the science curriculum and the ongoing discussions related to the introduction of the IBD which helped to shape the research questions. As a participant observer, the school provided the social context in which I used a variety of methods to collect information. The analyses evolved into a more interpretive case study of the constructivist model in which I used secondary voices to help to illuminate theory (Heron & Reason, 1997, in Lincoln and Guba, 2000). Hence, the present research does not comfortably fit into any one paradigm, but was essentially fluid due to its developmental nature.

The present study makes use of a collective case study approach to follow and examine the experiences of the students and teachers involved in the two courses (IBD and HSC). According to Creswell (1998, p. 61), a case study is the "exploration of a 'bounded system' or a case over time through detailed, in-depth data collection involving multiple sources of information". The present study involves Blackwood School as the case and focuses on an issue, the introduction of the international IBD curriculum alongside the local HSC curriculum.

3.3 SAMPLE

The present study aimed to be holistic in its approach to the evaluation of the new programme and its comparison with the existing local curriculum. According to Lincoln and Guba (2000), qualitative research often is based on a holistic view that social phenomena and the nature of cases are situational and influenced by happenings of many kinds. It was with this in mind that the present study sought to gather data from different participants to examine the complexities involved in the delivery of the two curricula as they were implemented.

The sample for the present study was purposefully selected from Blackwood School, an independent, non-selective K-12 school for girls with a high academic standing. The study involved three key sample groups, a group of three science teachers involved in teaching the two programmes, and two senior student groups, one studying IBD science and the other studying HSC science. These groups are each described below.

The study involved a group of three senior science teachers; two of whom had experience teaching in the HSC science programme and were selected to teach on the IBD science programme and one teacher who was teaching the HSC science programme. (All names used in the present study were pseudonyms.) The first teacher, Beryl, was a biology teacher who had taught the HSC science programme for over twenty years, fifteen of which were at Blackwood School. She had applied for and, based on her experience, was selected to teach biology on the IBD programme. The second teacher, Christine, also had over twenty years of experience teaching the HSC science programme, four of which were at Blackwood School.

Like Beryl, Christine also applied for and was selected to teach chemistry on the IBD programme. These two teachers volunteered to take part in the study. Their experience and ability to provide informed views on each of the curricula, made them valuable participants in the study. The third teacher, Heidi, had a rich background in teaching biology and chemistry overseas. This, in addition to her relative inexperience (one year) in teaching within the HSC system, made her a significant participant in the study. Heidi was teaching the HSC biology and chemistry during the course of the study.

The student sample for the present study included two groups, one group studying science in the IBD programme and one group studying science in the HSC programme. It was anticipated that a physics class would be run as part of the IBD science programme however, due to limited enrolments and budget constraints, this was not the case. For the group studying the IBD science programme, all 18 students were enrolled in either biology, chemistry, or both.

To ensure that the two groups were comparable in terms of subjects, only students enrolled in biology and chemistry classes were considered. Two other factors were also taken into consideration to ensure that the students enrolled in the HSC programme were comparable to those enrolled in the IBD programme. First, given that the size of a group and the amount of time that they spend together can affect the class dynamics, it was considered important to select a class that had these similarities. Second, to ensure that data collection could take place when required, the accessibility of the students was also considered.

One science class in the HSC programme covered the criteria for selection more suitably than the others. This class was comprised of students studying biology alongside other students who were studying chemistry in another class. Although the amount of time that these students spent together (about one-third of their classes) was less than the amount of time that IBD students spent together (around two-thirds of their classes), it was still more time than any of the other HSC science classes. The composition of the selected HSC science class also matched more closely the composition of the IBD group than any of the other HSC science classes. At the time of selection the HSC science class was comprised of 21 students and the IBD science group was comprised of 18 students, making them similar in size. Unfortunately, two students left the IBD programme within the first weeks of the study, making them less comparable. Finally, the selected HSC science class was taught by Heidi, who was supportive of the study and had indicated a willingness to be involved, making access to students for data collection easier.

As discussed, the selection of the two groups included only students who were studying biology and/or chemistry. The IBD cohort was made up of six students studying biology, four students studying chemistry and six studying both. In the HSC cohort, eight students were studying biology and thirteen students were studying both biology and chemistry. These figures are summarised in Table 3.1.

Table 3.1: Group Composition for the IBD and HSC Cohorts

Subject	Number of Students Enrolled in Each Programme	
	IBD Programme	HSC Programme
Biology	6	8
Chemistry	4	0
Biology and Chemistry	6	13
Total	(Initially 18) 16	21

3.4 RESEARCH METHODS

The present study sought to compare and evaluate the HSC and IBD in terms of the intended, implemented and achieved curricula using a combination of qualitative and quantitative methods and a rigorous approach to data collection. Keeve's model for curriculum implementation was used to examine the wider educational context within which the study took place (Keeves, 1974; 2004). This model provided a framework that helped to guide the collection and reporting of data in this thesis. The model examines three aspects of the curriculum, the intended curriculum, the implemented curriculum, and the achieved curriculum. The model moves the researcher from studying the macro, the national position on providing education; to the micro, the student position in receiving the education. It was within this broader framework that the IBD and HSC science programmes, were examined.

Multiple sources of information were collected, including curriculum documents (described in Section 3.4.1), quantitative data (described in Section 3.4.2) and qualitative information (described in Section 3.4.3).

3.4.1 Curriculum Comparison

The research design adopted by this study is underpinned by Stake's (1976) Responsive model and Stake's (1978, 2002) Case Study model. The twelve steps outlined in Stake's Responsive model were used to provide structure to decisions related to the research methods and sample selection. For example, the fifth step in Stakes responsive model is to identify the data needs with reference to issues (Stake, 1976). This required an analysis of the prescribed curricula, involving a close scrutiny and comparison of the science syllabus documents and related website contents for the IBD programme and the HSC programme as they "define and regulate educational practices and arrangement" (Freebody, 2003, p. 204). Stake's (1978) Case Study model was incorporated to enable the researcher to consider the views and values of all of the participants during the evaluation process and to draw on personal experience to help to inform the generalisations.

An initial review of the science curriculum documents provided for the IBD and HSC programmes identified two key areas which aligned with current educational research (Australian Council for Educational Research, 2001), these being, content knowledge and skills. Two models were selected to help to guide the comparative analysis. Halls' (1971) model was selected to help to compare the content and Gilbert's (2004) model was selected to help to compare the skills included within each curriculum.

To provide a detailed comparison of the science subject content in each of the programmes, the physics syllabi were compared. Physics was selected because, as a physicist, I was most familiar with the terminology and underlying content of this discipline. Halls' (1971) model for curriculum comparison was originally developed to examine the equivalence between international curricula to determine whether students were eligible for access to higher education. (See Section 2.4.1 for detail related to the development of this model.) As this study involved a comparison between an international programme (the IBD) and a local State programme (the HSC), this model was considered to be appropriate and was adapted for this purpose.

The comparison carried out by Halls, using the Dewey (n.d.) decimal system, provided a suitable model for this study. To compare physics topics taught within the curricula of his study, Halls (1971) divided high school physics into ten prime divisions and categorised them using an amplified Dewey (n.d.) decimal classification. For the present study, these categories were modified as some of them were out-dated and other, more contemporary subjects had not been included. For example, the traditional topic of hydrostatics, which was of sufficient importance to warrant two of Halls' ten divisions, is not addressed in either of the syllabus documents and has been replaced with topics that are now viewed as more relevant. Two new subjects, radiation (atomic and nuclear) and testing and measurement, were included in both syllabus documents to address more contemporary physics. To accommodate these additions, two new divisions were added, using the same classification system, namely: Testing and Measurement; and Radiation – Atomic and Nuclear.

To compare and analyse the skills content of related curriculum documents, a second model, developed by Gilbert (2004), as part of the Australian Council for Educational Research (2001) study, was utilised. This model provided a general framework for skills analysis that could be directly applied to the physics syllabi for both the IBD and HSC programmes to provide a means of comparison. Gilbert's model lists eighteen skills categories, including: basic information and communication; interpersonal skills and team work; effective participation and work in context; initiative and creativity; organisational skills; independent lifelong learning; personal development; deep learning/knowledge and employment skills/knowledge (Gilbert, 2004). In the present study, the number of references to each skill within each document was recorded and the results tabulated to assist with analysis and evaluation.

3.4.2 Collecting the Quantitative Data

To examine Research Objectives 3, 4 and 5, which are related to students' views, a selection of existing and researcher developed instruments were administered at different times during the study. Four questionnaires were used to help to compare the experiences of students in each of the programmes (IBD and HSC), namely, the Science Laboratory Environment Inventory (SLEI), the Multiple Intelligences Checklist for Adults (MICA), a questionnaire developed to provide an overview of students' aspirations and a students' attitude questionnaire was used to investigate students experience of their Year 10 programme. Each of these questionnaires is described below.

Science Laboratory Environment Inventory

To compare students' perceptions of their learning environment in the IBD and HSC programmes (Research Objective 3), the Science Laboratory Environment Inventory (SLEI; Fraser, Giddings & McRobbie, 1995) was administered to all of the students in both groups. The SLEI assesses students' perceptions of the laboratory learning environment using five dimensions or scales, namely Student Cohesiveness, Open-endedness, Integration, Rule Clarity, and Material Environment. Each of the five scales has seven items with a total of 35 items. Items are responded to on a five-point frequency scale of Almost Never, Seldom, Sometimes, Often and Almost Always. To guard against passive responses the SLEI is organised in a cyclic order and includes some negatively-worded items. Past studies that have used this instrument have reported strong reliability statistics (see Section 2.5.2 for more details on the development, use and validation of the SLEI). A copy of the SLEI is provided in Appendix A.

As the academic timetables were different for the IBD and HSC, the researcher was careful to ensure that administration of the SLEI did not clash with examinations in either programme. It was also considered important to allow sufficient time for a stable learning environment to be established and for students to be able to reflect on their experiences over a period of time. To satisfy both of these considerations, the administration of the SLEI took place at the end of the first year of the study.

Multiple Intelligences Checklist for Adults

To examine whether students' enrolled in each of the programmes (IBD and HSC) differed in terms of propensity to select a science related career, the Multiple Intelligences Checklist for Adults (MICA) was administered. The MICA was originally developed by McGrath & Noble (2005) to help to identify students' perceived strengths in the different areas of multiple intelligences.

The MICA's comprised 38 statements each of which were related to one of the eight areas of intelligence identified by Gardner (2003). Details related to each of the intelligence areas are provided in Section 2.5.3. The statements were responded to on a three-point personal assessment scale of Very True of Me, Somewhat True of Me, and Not True of Me. Within the instrument the statements are organised in random order. To analyse the responses, the statements were grouped into their related intelligences and the sum of a student's score for each statement in an area of intelligence were calculated. These totals were then ranked in a final table, the 'Relative Strengths Profile'. The intelligence areas with the top two and bottom two scores indicated a student's personal strength and weakness, respectively. Appendix B provides a copy of the MICA, the score chart and proforma for the Relative Strengths Profile used in the present study.

This data was used to help to identify patterns in students' perceived strengths for those intelligences that were considered to be aligned with science and, therefore, a more likely propensity for pursuing science-related degrees and careers. Although not reported in this thesis, the results also informed the teachers as to the strengths of their students to enable teaching styles to be adjusted to suit (Klein, 2003). The MICA was administered to all of the participating students midway through the second year of the study.

Interest in Science Careers

To complement the MICA and to further investigate whether either of the programmes was more likely to encourage students to pursue a science-related career (Research Objective 4), students were asked to respond to two statements. The statements were designed to examine whether students enrolled in each of the programmes (IBD and HSC) differed in terms of their interest in pursuing science as a career. These statements used a Likert-type response format of Strongly Disagree, Disagree, Agree and Strongly Agree. Students were asked the same questions at the beginning and at the end of the programme to examine whether their aspirations had changed over the course of the two year programme. These questions were 'I am considering a career in a science-related field' and 'I would like more information on science careers'.

Student Attitude Questionnaire

To compare the experiences of students enrolled in the two different programmes a questionnaire was developed in consultation with colleagues, to examine issues related to science education at Blackwood School. The aim of the questionnaire was to elicit information about students' attitudes (Appendix C, Section A) and views of their experiences of their selected senior programme (Appendix C, Section B). The questionnaire included 18 items, to which students responded using a Likert-type response format of Strongly Disagree, Disagree, Agree and Strongly Agree. Space was provided for students to write comments. In addition, three open-ended questions were included to give students the opportunity to respond freely. This questionnaire was administered at the end of the two year program.

Questionnaire to Investigate Year 10 Experience and Programme Selection

This questionnaire was developed in consultation with the science teachers involved in the study. The questionnaire included two sections designed to elicit information about students' reasons for their selection of programme (Appendix D, Section A) their attitudes towards their Year 10 science experience, (Appendix D, Section B) and perceptions of their Year 10 science experience (Appendix D, Questions 2-7). This questionnaire used a four point Likert-type response format of Strongly Disagree, Disagree, Agree and Strongly Agree. There were a total of 12 statements and additional space was provided after each of the three sections for written comments. Three open-ended questions were included to give students the opportunity to respond freely. This questionnaire was administered at the start of the two year program.

In addition to the questionnaires described above, data, related to student achievement, was collected from school documents. This data was related to students' final examination results and their University Admissions Index.

3.4.3 Gathering the Qualitative Information

An important component of the present study was the gathering of qualitative information. Whilst quantitative data was used to provide an overview of students views of a range of factors, qualitative information provided the researcher with deeper insights of a range of phenomena. During the two-year study, qualitative information was collected using interviews, observations and anecdotal data, each of which are described below.

Interviews

Interviews with a range of participants were conducted over the two years of the study. The selection of interview type was determined by a) its usefulness in answering the research questions and b) the participant involved. According to Anderson (1998) and Anderson and Ferguson (2007), interviews have a complementary range of strengths in that the personal interaction involved can give value to both the topic and to the views of the interviewee. Interviews were selected as a source of data for the present study as they permitted the researcher to pay attention to individual differences, and to obtain non-verbal data (Partington, 2001). Both of these features gave depth to the findings.

In each case, interviews were conducted face-to-face with participants. Interviews were recorded using hand written notes during the interviews. To clarify and validate these notes, they were read back to the interviewees for reflection and confirmation. For the present study, three types of interviews were conducted over the course of the two years, namely, in-depth interviews, focus group interviews and informal conversational interviews.

In-Depth Interviews. At the beginning and end of the study, in-depth semi-structured interviews were held with the school principal, IBD coordinator and the three participating science teachers. These interviews allowed the researcher to focus the responses within pre-established categories, whilst leaving room to allow the respondents to provide greater depth if desired. Interviews with the science teachers, familiar with the student groups and the delivery of the established HSC curriculum, enabled a series of benchmarks to be constructed as a comparison and to help to identify the new dynamics of the IBD programme (Keeves, 2004). Further interviews with the science teachers were held at strategic times during the study as issues arose.

Focus Group Interviews as described by Patton (2002, p. 385), were considered to be most appropriate for use with students in the present study as they are likely to provide a variety of perspectives that would be discussed in a more social context. Focus group interviews were held separately for students enrolled in the IBD and HSC programmes. Focus group interviews were held on four occasions with each of the IBD and HSC groups immediately after the administration of each instrument, to provide students with the opportunity to reflect on the instrument, comment and expand on responses to individual items, and to elucidate problems that they might have encountered (Lewis, 2000). Attendance in focus group interviews was voluntary, however, the majority of the students in each group took part each time.

Informal Conversational Interview. Patton (2002) suggests that conversational interview constitutes a major tool of field work. These interviews were used throughout the study. They were unstructured to provide maximum flexibility in terms of the type of information to be collected and allowed the researcher to approach teachers on different occasions during the implementation of the programme to help to clarify, expand on previous responses, or to help to elucidate new problems emerging from the data. These interviews were used prior to the start of the programme and then throughout the two years of the main study, when required, and for different reasons. For example, some of the informal conversations were held after classroom observations to answer queries that emerged. These interviews were recorded in the researchers' journal.

Direct Observation

Observations were conducted once in each of the science classes during each of the four semesters of the study, to provide insights into the teaching and learning opportunities and the classroom culture. An effort was made to observe different activities on each occasion so that the content, teaching and learning could be compared and contrasted. Each occasion was on the invitation of the class teacher and for the full 50-minute lesson. Observations were carried out openly and as a non-participant, except when practical sessions gave the opportunity for closer interaction with the students to better ascertain their level of understanding. Field notes were used to record the observation data.

Anecdotal Data

Within the school community the researcher was a participant observer, and everyday interactions between staff and students were considered to be a rich source of data (Anderson & Ferguson, 2007; Stake, 1995). Hence, anecdotal data, related to the implementation and delivery of the IBD science courses, was collected throughout the two years from both teachers and students. This data was recorded in the researcher's journal.

3.5 ANALYSIS OF THE DATA

The analysis of the different forms of data collected during the study involved document data analysis (described in Section 3.5.1), quantitative data analysis (described in Section 3.5.2) and qualitative data analysis, used to help to explain and enrich the overall findings (described in Section 3.5.3).

3.5.1 Document Data Analysis

For the present study, to obtain information about the intended curriculum, document data was collected from the syllabus and associated documentation provided by the IBO and BOS. These data were supplemented with information made available on the respective websites to provide a more comprehensive picture. The models selected (Halls, 1971; Gilbert, 2004) to compare the content and skills taught in the respective curricula, provided a framework by which to display the data and to assist with comparison and analysis. Areas of similarity and disparity were sought from the tables of data, so that an overview could be provided. This revealed areas deemed to be of greater or lesser importance within the respective curricula, depending on the emphasis given to each area in the curriculum-related documents.

3.5.2 Quantitative Data Analysis

For the present study, quantitative data related to each student group was examined using four instruments as an efficient means of collecting group information. This information provided an overview of student opinions and perceptions which could be used to guide interview and focus group questions, as recommended by Creswell (2002). Despite the fact that the sample of students was small (37 students), in-depth qualitative information helped to clarify and explain the quantitative data collected. In this respect, sequential procedures, as described by Creswell (2002, p. 16), were adopted whereby the researcher “elaborated on or expanded the findings of one method with another method”. Data associated with the students’ final examination results and their UAI were collected from school documents.

Descriptive analysis was used to help to display the data graphically, in the form of profiles and in tables, providing a means by which the two groups could be compared easily and to help to illustrate trends that were present. It also helped to show more clearly whether any patterns were emerging (Huberman & Miles, 1994), and assisted in the verification of the other findings. For the SLEI, t tests for independent samples were used to examine whether differences between the two groups were statistically significant and effect sizes were used to examine the size of the difference in standard deviations.

3.5.3 Qualitative Data Analysis

The analysis of the qualitative data was descriptive, following a model of ‘grounded theory’ advocated by Glaser and Strauss (1967, in Burgess, 1990). Common categories were identified within the collected data which were further developed using the four stages established by Glaser and Strauss (1967). These stages involved: (1) comparing items within the categories; (2) integrating the categories; (3) reducing the categories to the main areas to be studied; and (4) identifying the major themes for further investigation.

The backbone of quantitative data was taken into consideration during the analysis of the qualitative data so that an interrelationship was developed between the different data types as the programmes moved through their two year calendar cycles. This form of "… back-and-forth interplay with data …" (Strauss & Corbin, 1994, p. 282) resulted in a process referred to by Denzin & Lincoln (2005) as the researcher acting as 'bricoleur' that involves assembling "images into montages" (Denzin & Lincoln, 2005, p. 4). These interrelationships resonate also within Stake's Case Study model (1978), which advocates that information collected from the various sources should be scrutinised and pieced together for congruence, to make more sense of the data.

The perceptions of the participants involved in the study (staff, students and coordinator) each contributed to the data as they implemented and experienced the respective curricula. As various themes started to emerge, triangulation (Denzin, 1978) took place between the different research methods. Triangulation was used as a technique in which the multiple research methods, including questionnaires, interviews and observations, were used to improve the validity of the findings. According to Mathison (1988) when the findings were in agreement convergence was said to have occurred, other findings might be in disagreement, or contradictory. In cases where the findings, obtained through triangulation, showed inconsistency, the researcher constructed plausible explanations for the phenomena, leading to possible further research.

3.6 ADDRESSING ETHICAL CONCERNS

Anderson (1998) refers to the codes of ethics and controls that are now in place to protect people participating in the research processes, particularly social research. He acknowledges that the existence of these bodies does not guarantee ethical practice, and that, ultimately, the responsibility is that of the researcher. Mason (1996) is of the view that ethical concerns should be high on the agenda of any researcher and should be built into the initial design stage. During this study I carefully considered the openness and transparency, (discussed in Section 3.6.1) and organisational issues related to the student (discussed in Section 3.6.2) to ensure that participants were not disadvantaged by the study, and to maintain the validity and reliability of the reporting process.

3.6.1 Openness and Transparency

Mason (1996) highlights that most ethical codes suggest that research should not be conducted in a covert or deceitful manner, and that each group should be clearly informed of the researcher's role and status. The present study involved two groups of people, students and teachers, who contributed to the data collection at different stages of the research process. All of the participants were provided with detailed information about the study including an explanation of the purpose of the research and the procedures that were to be used. Participants were given the opportunity to ask questions about the research procedures and were informed that participation in the study was voluntary that they had the option to withdraw at any time. In addition, because these participants were minors, parental permission was sought and obtained before they took part in the research activity. A copy of the parental permission letter is provided in Appendix E.

To ensure confidentiality, the anonymity of the participants was maintained at all times. All questionnaires were anonymous, a process that enabled students to submit comments privately, and pseudonyms were used in all records and notes made during focus group interviews and in journal records.

As a teacher within the school, I acknowledged that, potentially, power relationships between the student and myself could be an issue (Fraser, 1998b; Punch, 1998). To address this, I was clear about the incentives for joining the research group. Although lollies were given to students to thank them for their time, it was made clear that they would not receive better grades or privileges for taking part.

All interviews were carried out by myself, an employee of the school, and I had therefore undergone a police clearance check, a State requirement when working with minors. The research was periodically reviewed by the IBD programme coordinator so that regular feedback could be given and the issues shared. The school principal was included in the initial research project plan and a presentation, supported by the principal, was made to the school management team, giving the study status and validity within the school community.

3.6.2 Organisational Considerations

One of the concerns identified in the Australian Association for Research in Education code of ethics is that no harm should come to any of the participants within the study (Australian Association for Research in Education, 2005). In the case of the present study, the practicalities of data collection, such as administering instruments and conducting interviews were considered in relation to the possible disadvantages to the students as a result of their involvement. Three organisational issues, that could potentially disrupt student learning, were identified as the timing of data collection, rewards for students and consideration of the teachers' needs. These issues and how they were addressed are discussed below.

Consideration was given to ensure that data collection did not require students to miss any part of the curriculum, or disrupt the dynamics of a class. Therefore, data collection usually took place during lunch breaks. A room for interviews was allocated on the school campus, so that travel could be kept to a minimum. Timing was also considered for teacher interviews, to reduce interruptions, an off-campus venue was used (Anderson, 1998).

As a number of the students' board at the school, several from overseas, a longer timeframe was required to obtain parental permission to enable them take part in the study. To reduce the stress of the boarders, who were keen to participate, a longer permission-return date was set.

According to Anderson (1998), benefit should occur for the participants by their participation in the research as well as by the results. An intrinsic reward was to provide students with a voice that could influence the school experience for future students. To ensure that more extrinsic rewards could not be construed as inducement, these were limited to stickers or lollies provided to thank them for participating in focus group interviews.

According to Australian Association for Research in Education (2005), researchers need to be aware of and take into account the fact that their perception of harms and benefits may not be those of the participants (Australian Association for Research in Education, 2005). To address this, teachers were invited, at various intervals during the study, to express their concerns regarding the study. In this way action could be taken to minimise disruptions and inconvenience to either the students or teachers.

3.7 CHAPTER SUMMARY

Chapter three describes the research methods used to compare and evaluate the IBD and HSC science programmes, in terms of the intended, implemented and achieved curriculum. The purpose of the present study was two-fold: first, to provide a formative evaluation that could be used to guide improvements in the delivery of the programmes at Blackwood School; and second, to provide a summative evaluation that could be used to inform decisions about whether running parallel programmes could be recommended to other schools.

The theoretical framework of the study involved a developmental process that built on the literature review and revealed a range of paradigms. The study commenced from a more positive approach but, as the study progressed, there was some movement between paradigms.

The study incorporated a mixed-method approach in which quantitative and qualitative research methods were used. The study followed a sequential procedure in which one method was used to elaborate and expand on another (Creswell, 2002). Keeves' (2004) model provides a broad framework for the collection, analyses and representation of the data in terms of the intended curriculum (examined using syllabus documents), the implemented curriculum (examined using the views and perspectives of the teachers and the students) and the achieved curriculum (examined using students' views and University Admissions Index scores).

To help to answer the first research question, I chose two models to help guide the comparison of the intended curriculum of the IBD and HSC physics programmes. Hall's model (1971) was used to compare the content knowledge of the two physics courses, and the skills to be taught in each programme were compared using Gilbert's model (2004). A range of documents including the respective syllabi, course guidelines, examination papers and websites were used to help inform the comparisons. Analyses of the data involved scoring the number of references to each topic or skill within each document. The results were then tabulated to assist with analysis and evaluation.

To help to provide insights into the implemented curriculum the views of the teachers and students were sought. Qualitative information was used to help to enrich and inform the quantitative data. To collect quantitative data, four questionnaires were used. Given that the laboratory activities are considered to be an important component of a senior science programme, the Science Laboratory Environment Inventory was used to provide a comparison of students' perceptions of important aspects of their laboratory environment in each of the programmes.
The Multiple Intelligence Checklist for Adults (MICA) was used to provide data related to the multiple intelligences of the students (McGrath & Noble, 2005). It was anticipated that the areas of strengths for students who elected to study the IBD (in which science was a compulsory subject) might differ to those who elected to study the HSC (in which the study of science was optional). It was anticipated that, by identifying students' perceived areas of strengths it might help to provide an indication of their propensity to select a career in science.

Two questions were asked of students at the beginning and at the end of the two-year study to determine whether changes in students' interest in pursuing a science-related career had changed. A questionnaire, designed by the researcher to examine students views on various aspects related to the two programmes, was administered to students at the end of the study. This questionnaire was designed to provide an overview of students' views of their experiences in their chosen science courses. To provide an indication of whether students felt that their Year 10 science programme had adequately prepared them for their selected science programme for Year 11 and 12, the researcher developed a questionnaire. This questionnaire was administered at the end of the two-year study to provide an overview of students' views.

In all cases, qualitative information was used to provide deeper insights and understandings into the quantitative data. The gathering of qualitative information was an important component of the present study, providing opportunities for participants to raise issues and to express their views and opinions on a range of aspects. Several methods were used for gathering qualitative information, including interviews, direct observations and anecdotal data.

Interviews included in-depth interviews, focus group interviews and informal conversational interviews. In-depth interviews with teachers were held at the beginning and at the end of the two-year study. These interviews were supplemented with informal conversational interviews that were conducted, with the teachers as needed, throughout the two-years. Focus group interviews were conducted with students after the administration of each questionnaire. These sessions provided with a les formal, social setting, in which they were able to share their views, ideas and experiences.
Due to the variety of data collected the quantitative data, collected using the different instruments, these findings were inextricably linked with the process of qualitative data analysis. Issues raised by these methods were considered and research theories were applied to the study to give perspective and clarity so that conclusions could be drawn.

Of importance to the researcher was the need to address all ethical concerns and considerations that were raised prior to and during this study. Three major issues were considered, these being, openness and transparency and organisational considerations and issues related to the reporting of research findings. To address the issue of openness and transparency, the researcher went to great lengths to ensure that teachers, students and their parents were informed of the purpose of the study and the expectations of the participants. For both staff and students anonymity was maintained throughout the study, timing and venue were considered so as not to disrupt work and for confidentiality. Parental permission was obtained to enable the students to take part in the study, and it was made clear that there was no inducement or retribution for participants.

The study was broad in that it sought to investigate the two programmes in terms of the intended curriculum and experienced curriculum. Quantitative and qualitative data was collected for the study in order to give a comprehensive overview which was supported by a range of specific details. Triangulation of these methods assisted in providing deeper insights. The wide range of strategies used for collecting the data was chosen in order to provide the maximum information possible to the stakeholders in the school community.

The next two chapters are devoted to reporting the results of the study. Chapter 4 compares and evaluates the intended curriculum for the IBD science programme and the HSC science programme in terms of its content, objectives and assessment methods. Chapter 5 reports the comparison of selected aspects related to the implemented curriculum and the achieved curriculum for both the IBD and HSC science programmes.

CHAPTER 4

RESULTS: COMPARING THE INTENDED CURRICULA

The overarching aim of the present study was to compare and evaluate the IBD (an international curriculum introduced at the school at the commencement of the study) and the HSC (the local curriculum offered state-wide). As a first step, a comparative analysis was used to provide an understanding and overview of the intended curricula provided for each. This stage of the study made use of two comparative curriculum models to examine and compare various aspects of the IBD and HSC science curricula in general and the physics programme in particular. As a physicist, I was most familiar with the terminology and teaching and learning required in this discipline, making physics the obvious choice for comparison.

The key components of Keeves (2004) model, illustrated in Figure 4.1, were applied to give structure to the overview of the two programmes. Keeves' model was originally developed in 1971 and works on the premise that the intended curriculum is set within the context of the education system, implemented within a classroom in a school, and relates ultimately to the outcomes of the individual student. The *context* column (centre) has three levels moving from a description at the macro level (system-wide) down to the micro level (the student). The context is framed by the *antecedents* (first column), or the situation in which the context is embedded and by which it is strongly influenced. The *curriculum* column (third column) describes the product to be delivered (intended, implemented and achieved curriculum). The arrows provided in Figure 4.1 indicate the direction of influence, which is from left to right across the columns, but can be up or down between the rows. Using Keeves (2004) model for curriculum implementation provided a framework within which the distinctiveness and merits of the IBD and HSC could be examined.

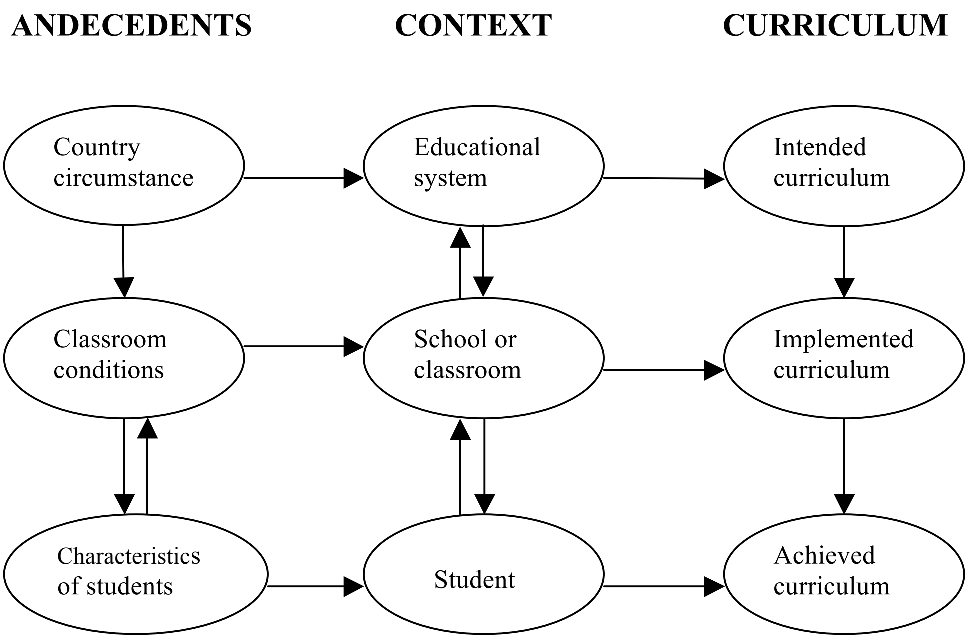


Figure 4.1: The Context and Components of the School Curriculum (Keeves, 2004)

This chapter examines the first row of the figure in terms of the country circumstances (antecedents), educational system (context) and intended curriculum (curriculum). Chapter 5 reports the findings related to the second and third levels of Keeve's model, in terms of the classroom conditions and characteristics of students (antecedents), the school or classroom and student (context) and the implemented and achieved curriculum (curriculum).

This chapter is devoted to describing the findings of the first research objective:

Research Objective #1

> To investigate whether differences exist between the IBD science programme and the HSC science programme in terms of the curriculum content, objectives and assessment requirements.

To compare the intended curricula, syllabus documents and website programme statements were used to examine the curriculum content, objectives and assessment of the HSC and IBD physics courses. A review of the literature, reported in Chapter 2, was used to help to identify important aspects of the science curriculum that were compared for the purpose of this study. This chapter discusses the comparison of the intended curricula using the following headings and section numbers:

4.1 Antecedents and Context of the Intended Curricula;
4.2 Curriculum Content;
4.3 Aims and Objectives;
4.4 Assessment Methods as Mandated by the Organising Bodies; and
4.5 Chapter Summary

4.1 ANTECEDANTS AND CONTEXT OF THE CURRICULA

The description and evaluation of a curriculum needs to be done in context if it is to be meaningful (Keeves, 2004). Using the first row of Keeves (2004) model, Table 4.1 provides a summary of the antecedents (country circumstances) and contexts (educational system) as they apply to the intended curricula of the two science programmes (IBD and HSC) at Blackwood School.

Table 4.1: Comparing the Context and Components of the Blackwood School Science Curriculum for the IBD and HSC using Keeves' (2004) framework

	Antecedent	Context	Curriculum (science)
Level 1			
IBD	Australia/NSW Sydney, private school.	International Educational Organisation – IBO. Based in the Northern hemisphere.	Group 4 in a six group, two-year course. Recently updated syllabus content. Traditional science content. One science and one mathematics subject is compulsory.
HSC	Australia/NSW Sydney, independent school.	State educational organisation – Board of Studies (BOS).	Science is an optional subject in a two-year course. Recently updated syllabus to include history of scientific thinking. Mathematics is advised but not compulsory.

This section is devoted to describing the antecedents, in this case the country circumstances (Section 4.1.1), the educational context of each of the curricula (Section 4.1.2), and the organisation of the teaching hours of the respective curricula (Section 4.1.3).

4.1.1 Country Circumstance

The antecedent for both groups of students is the location which, in this case, is Sydney, a large city in New South Wales, Australia. Australia is a wealthy, developed country with an excellent standing in science education, in that it regularly achieves a position in the top ten of the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study report (TIMSS) (Organisation for Economic Cooperation and Development, 2007).

Within this context, Australia has a public education sector that is government funded and managed by state curriculum bodies. There is also a large independent education sector which receives some government support but is funded mainly by religious organisations, tuition fees, or a combination of the two. There is presently a system of centralised curriculum development that is run by the individual states. Whilst the consultation process for curriculum is reported to be open, generally, there is no effective means for the general population to either provide input or to exert influence over the content of school curricula in Australia (Board of Studies, 2002b; Farrelly, 2005).

Each state has its own curriculum which has resulted in inconsistencies in senior secondary school curricula across Australia (Department of Education, Science and Training, 2006). These inconsistencies are observed in areas such as: the use of terminology within the curricula; subject content; assessment and reporting; and how vocational learning is incorporated. These inconsistencies have led the Federal Government to decide that all states and territory will follow a national curriculum, with a national assessment, created by a national standards body. It is argued that a single national high school qualification will solve the problems of impoverished curricula, weak standards and state-based inconsistencies by creating a more rigorous benchmark for achievement (Farrelly, 2005). The Australian Council for Educational

Research report, *Australian Certificate of Education: Exploring a way forward* (Department of Education, Science and Training, 2006) provides four models that could be used to address these issues, one of which is a national certificate modelled on the International Baccalaureate.

David Kemp (2006), the education minister from 1996 to 2001, recognised that, if schools in Australia were free to choose a national curriculum, parents moving interstate could choose a national curriculum school for their child, whose curriculum would be the same as that of the school that they left. This would cause minimal disruption for both the student and the school. He observed that the principle of choice of curriculum had already been accepted and that several independent schools in each state were offering the IBD as an alternative to the state curriculum.

It is within this climate that the International Baccalaureate Organisation provides an appealing, established and authoritative alternative for independent schools in New South Wales. Research indicates that there are now more than 4000 students registered at over 500 schools across 125 countries studying the International Baccalaureate Diploma (International Baccalaureate Organisation, 2009).

Since 1979, when the first Australian school offered the IBD the number of independent schools to introduce the IBD alongside the state curriculum has steadily increased (Bagnall, 1994; Buckingham, 2006; Farrelly, 2005; Kemp, 2006). There are currently 59 Australian schools offering the IBD (International Baccalaureate Organisation, 2009) and Blackwood School is one such school that has opted to include the IBD alongside the state HSC curriculum.

The following section is devoted to providing a description of the educational context in terms of the overarching philosophy and governing body of the IBD and the state HSC curriculum.

4.1.2 Educational Context – Introducing the Two Programmes

The International Baccalaureate Diploma (IBD) and New South Wales Higher School Certificate (HSC) have similar aims in that they both intend to provide an academic framework for senior secondary school students to demonstrate their ability in order to gain access into tertiary education. However, they are different in structure, scope and delivery.

This section provides a broad introduction and overview of the main philosophies of the two organisations that are responsible for the respective curricula: the International Baccalaureate Organisation (IBO) responsible for the International Baccalaureate Diploma (IBD) and the New South Wales Board of Studies (BOS), responsible for the Higher School Certificate (HSC). The organisations differ both historically and structurally (Hugman, 2008).

International Baccalaureate Organisation (IBO)

The International Baccalaureate Organisation (IBO) is based in the United Kingdom and has a worldwide network of member schools. Schools interested in introducing the IBD are required to undergo an extensive interview process before being considered for membership within the organisation. The IBO is funded by school membership fees, income from workshops and catalogue sales, and donations for development projects.

The International Baccalaureate programme is offered as three separate components, the primary school, middle school and senior school and is designed as a continuum of education. The IBD is the senior component of this continuum. The annual enrolment rate for the three components offered by the IBO (primary school, middle school and senior school) indicates strong growth and, in 2008, the IBO was teaching over 700,000 students worldwide across all of its programmes. The IBO recognises the challenge of their rapid rate of expansion and their marketing statement claims that the organisation intends to manage the growth whilst maintaining their reputation for high quality (International Baccalaureate Organisation, 2009).

The IBO aims to assist students in the development of, not only the intellectual but also the personal, emotional and social skills that enable a student to live, learn and work in a rapidly changing world. A full range of support services and resources are provided by the IBO to member schools, including, detailed curriculum guides for each programme, on-line resources and discussion networks, teacher training workshops and external assessment of students' work.

The IBD programme is designed to be undertaken as a holistic educational experience for each student.

The intended curriculum framework for the IBD consists of seven sections: six academic groups and a compulsory core. The compulsory central core is comprised of the Theory of Knowledge (TOK) unit, the Creativity, Action and Service (CAS) unit, and an extended essay. The Theory of Knowledge (TOK) unit is intended to provide coherence to the disciplines and involves perspectives from a variety of cultural roots. The Creativity, Action and Service (CAS) aspect of the programme is implemented to encourage the personal development and social conscience of the student beyond the academic sphere. Finally, students are expected to write an extended essay which allows them to pursue a topic of their choice and to develop their independent study skills. Around this compulsory central core, students may select subjects within each of the six set disciplines or 'groups'.

The six academic groups are comprised of: Group 1, Languages (literature in students' first language); Group 2, Second Languages (a language other than the student's first language); Group 3, Individuals and Societies (including subjects such as economics and geography); Group 4, Experimental Sciences (including subjects such as physics and chemistry); Group 5, Mathematical and Computer Sciences (including mathematics at different levels and computer sciences); and Group 6, The Arts (including subjects such as visual arts and music). Figure 4.2 provides a diagram of the structure of the IBD.

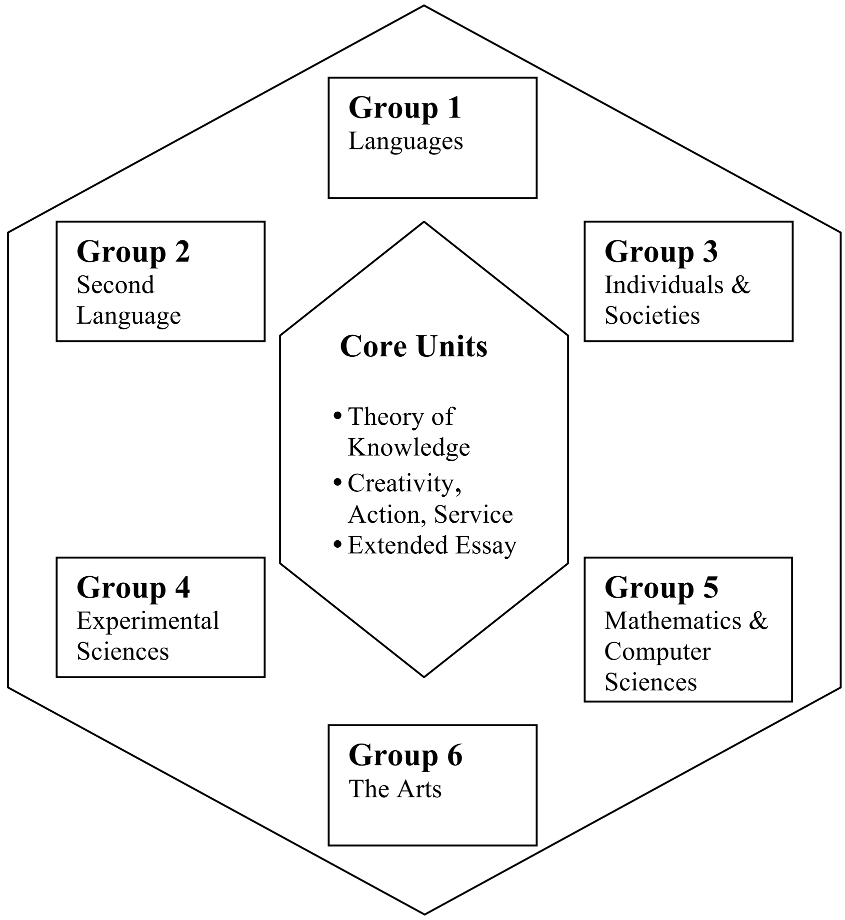


Figure 4.2: Structure of the International Baccalaureate Diploma Programme (Adapted from International Baccalaureate Organisation, 2004)

To qualify for the IBD, the compulsory central core, in addition to one subject from each of the six academic groups are required to be completed to a satisfactory standard. Subjects may, however, be studied in isolation for a certificate qualification, which is popular in the U.S. where students can use them as 'added extras' to their State curriculum (Mathews & Hill, 2005).

The experimental sciences (Group 4), is of particular interest to this study as it is this group that will be compared with the HSC science subjects. Experimental science subjects offered by the IBO are biology, chemistry, design technology, environmental systems and physics. However individual schools may select which subjects to offer depending on staff availability and enrolment numbers.

New South Wales Board of Studies (BOS)

In Australia, each state and territory has an organisation responsible for curriculum development and the national Department of Education, Science and Technology (DEST) oversees these state curriculum bodies. In the state of NSW, the curriculum body is known as the Board of Studies (BOS) and is based in Sydney. Independent schools are registered by this body and are educationally and financially accountable to the Board. The Board of Studies is responsible for and governs all aspects of the curriculum and is funded wholly by the national department.

The HSC provides a menu of unrelated subjects, of which only English is compulsory. Subjects are selected initially by the school after which students may elect to study any number of subjects, but are required to pass ten units (five two unit subjects or combined with more advanced, one unit subjects) to be considered for standard tertiary entrance. Each science subject is worth two units of study. A few subjects are also offered with one unit at an advanced level, for example English and mathematics, but there are no advanced science courses.

The HSC is not considered to be a holistic programme, as each subject stands in isolation rather than part of a larger integrated scheme. However, the HSC subject syllabi state that the intention is to “foster the intellectual, social and moral development of students” and to “provide a flexible structure” (Board of Studies, 2002b, p. 5).

Governance of the BOS is performed by a full-time president, three ex-officio members, and 19 members with particular knowledge and expertise in specific areas of education, that are appointed by the Minister for Education and Training. Non-government schools, such as the one in this study, are required to undergo a registration and accreditation process every six years to enable them to offer the HSC curriculum and to receive government funding. In 2008, nearly 68,000 students attended 750 HSC examination centres (Board of Studies, 2009), a slight increase over previous years.

Similar to the IBO, NSW schools have access to the BOS website which provides guides and resources designed to support their management and curriculum delivery.

Workshops and meetings for teachers are provided by BOS liaison officers who are strategically located around the state. Support is also offered via the BOS website for both students and parents.

The study reported in this thesis is focused on IBD Group 4, the Experimental sciences and the corresponding HSC science subjects of biology, chemistry and physics.

4.1.3 Organisation of Teaching Hours in the Two Curricula

Whereas the previous section describes the organisation of and the governing body responsible for the two curricula, this section examines the organisation of the curricula with respect to the duration of the course and the teaching hours required for each. There were many similarities in that both programmes were two years in duration, and each had three sections: compulsory core topics (that all students take), optional topics (that individual teachers select) and practical work. Both programmes also had a proportion of internal assessment and external examinations. Although science students on both programmes completed a two year course of study, they had quite different formats which are described in detail in this section.

Within the IBD programme there were two levels of study, the Standard Level and the Higher Level. Both levels involved a two year programme. The Standard Level involved 150 teaching hours and is assessed externally at the end of the two-year programme. More advanced students could choose to study the Higher Level of study which involved an additional 90 teaching hours. The Higher Level involved studying the same topics as the Standard Level but in greater depth. Students select the level of study, Standard or Higher, mid-course the Higher Level of study involves extra teaching hours and additional external assessment at the end of the two-year programme. To qualify for a full Diploma, and hence university entry, IBD students were required to study three academic subjects at the Higher Level, and three at the Standard Level as well as completing the three underpinning interdisciplinary compulsory unit activities (Theory of Knowledge, Creativity, Action and Service and extended essay). It was the IBD Higher Level course that more directly compared with the HSC in both teaching hours and content. All content taught in the first and second year of the programmes were externally assessed at the end of the two year programme.

Unlike the IBD, that offered students a choice of levels, only some HSC academic subjects, such as mathematics, had a single extension unit available. This extension level, however, was not available for any of the science subjects. The HSC, like the IBD, involved a two year course. The first year is considered to be a preliminary course and involved 120 teaching hours. This first year is not externally assessed and does not count towards university admission but was, however, a prerequisite to entering the second year of the HSC course. The second year involved 120 teaching hours, making a total of 240 teaching hours. Unlike the IBD, only the content taught in the second year of the programme was externally assessed.

There were similarities between the total teaching hours required in each curriculum, with respect to the class contact time and assessment allocation. The IBD Standard Level included a total of 150 hours of teaching and the IBD Higher Level and HSC both included a total number of 240 teaching hours. There were some differences, however in the division of time for each. For the IBD programme, the time required to be spent on theory and assessment was clearly divided with 40 hours of the Standard Level course and 60 hours of the Higher Level course being allocated to practical work. In contrast the HSC stipulates that 25-50% of class time must be allocated for practical work but did not specify how the time must be divided between theory and assessment. Table 4.2 provides a summary of the teaching hours for the two programmes.

Table 4.2: Comparing the Hours of Study for Assessment Within Each Syllabus (IBD and HSC) Over the Two Year Programme.

Course	Teaching Hours Over Two Years		
	IBD Standard Level	IBD Higher Level	HSC
Core subjects	80	135	210
Option subjects	30	45	30
Total theory hours	110	180	N/A
Internal assessment	40	60	N/A
Practical work	40	60	80
Total assessed hours	150	240	240

For the IBD programme, students were expected to select and study one subject from each of the six compulsory academic groups, described in Section 4.1.2, as well as the three interdisciplinary compulsory central core units. Science subjects, including biology, chemistry and physics were included within the Experimental Sciences (Group 4). Within the IBD, the study of one science subject was compulsory, although students can choose to study additional science subjects. Within the HSC programme, however, the study of a science subject was optional and the selection of a science subject was independent of all other subjects that a student might take.

A final significant difference was that the whole IBD programme must be completed to successfully qualify for a University Admissions Index (UAI) score for tertiary entrance. However, for an HSC student, a minimum of any 10 HSC units (usually five subjects at HSC level) were required to qualify for a UAI.

In summary, although the total number of teaching hours for each subject within the two programmes was comparable, these hours were allocated quite differently in terms of the amount of time spent on theory, assessment and practical work. The next section is devoted to examining the curriculum content of each programme.

4.2 CURRICULUM CONTENT

To make a comparison of the intended science curriculum content within the IBD and HSC programmes, physics was selected. As a first step towards comparing the content of the respective physics courses, it was necessary to examine the syllabus documents, associated support documents and websites for both the IBD and HSC programmes. All science courses in both the IBD and HSC programmes were comprised of compulsory core topics and optional topics. This section examines the course content in terms of the core and optional topics included in each (Section 4.2.1); the physics topics taught (Section 4.2.2); and the breadth and depth of the physics topics in each (Section 4.2.3).

4.2.1 Physics Course Content

A comparison of the composition of the two courses, the IBD and HSC, indicated that the topics to be studied were similar in nature. The core subjects required for the Standard and Higher Level IBD courses were also similar, however the amount of time spent on each reflected the additional depth required at the Higher Level. The HSC Year 12 core topics build on and extend those topics studied in the Year 11 topics.

In general, topic names in the IBD course reflected the branch of physics being studied within that topic. The HSC course, on the other hand, included topic names that were not related necessarily to the content. For example, the topic 'Space' involved the teaching of mechanics. For the Standard Level IBD the teacher had a choice of eight options from which two must be selected. Both the Higher Level IBD and the HSC teachers had five options from which the teacher was able to choose from. For the HSC, one option topic was selected by the teacher and for Higher Level IBD two optional topics were selected. For both the HSC and IBD, the teacher's final choice of option topic was likely to be influenced by the composition of the student group, their personal area of interest or expertise and, in the case of IBD, the number of students opting to study for the Higher Level.

To make the comparison clearer, the composition of the IBD and HSC physics courses are summarised in Table 4.3. The first column divides each course into the two distinct levels, the IBD is divided into the compulsory Standard Level and the optional Higher Level and the HSC is divided into the Year 11 preliminary course and the Year 12 HSC course. The table lists the core topics to be studied at each level, the optional topics that a teacher can select from and the teaching hours allocated for each. The total number of hours for each course includes the hours allowed for the options.

To compare the curriculum content of the IBD and HSC programmes, with respect to the physics courses, a model, developed by Halls (1971) was adapted, the results of which are described in the following section.

Table 4.3: Comparison of the Core and Options Included in the IBD and HSC Physics Courses

Programme	Core	Time (hours)	Options	Time (hours)
IBD			Teachers choose 2 from:	
Standard Level	▪ Physics and physical measurement	11	▪ Mechanics extension	15 each
			▪ Quantum physics and nuclear physics	
	▪ Mechanics	24		
	▪ Thermal physics	11	▪ Energy extension	
	▪ Waves	10		
	▪ Electricity and magnetism	15	And	
	▪ Atomic and nuclear physics	9		
	Group 4 Project	10-15		
Higher Level	▪ Measurement and uncertainty	2	▪ Biomedical physics	22 each
			▪ History & development of physics	
	▪ Mechanics	15		
	▪ Thermal physics	6	▪ Astrophysics	
	▪ Wave phenomena	8	▪ Relativity	
	▪ Electromagnetism	9	▪ Optics	
	▪ Quantum physics and nuclear physics	15		
	Group 4 project	10-15		
HSC			Teachers choose 1 from:	
Year 11	▪ The world communicates	30		
	▪ Electrical energy in the home			
	▪ Moving about			
	▪ The cosmic engine			
Year 12	▪ Space		▪ Geophysics	30 each
	▪ Motors and generators		▪ Medical physics	
	▪ From ideas to implementation		▪ Astrophysics	
			▪ From quanta to quarks	
			▪ The age of silicon	

4.2.2 Physics Topics

Close scrutiny of Halls' (1971) model revealed that the content of senior school physics courses have changed somewhat since it was developed over thirty-five years ago. To make Halls' model useable, new topics were identified, coded and added to the existing model. The data was then tabulated to assist with the comparison. These existing additions (Testing and Measurement; and Radiation – Atomic and Nuclear) comprise the last two rows of Table 4.4.

Table 4.4 uses Halls' (1971) model to illustrate how the physics topics within the two programmes were compared. Column 1 lists Halls' ten prime divisions, as well as the divisions added for the present study to update the list, linked to a Dewey classification number in Column 2. The topic of each prime division is identified in the third column. The last two columns (Columns 4 and 5) indicate, with a tick, whether this topic was present within either the HSC or IBD syllabus document.

The content of the syllabus documents for the IBD and HSC programmes were scrutinised for congruence with Halls' ten prime divisions and scored within the table. The major difference observed between the two programmes was that the teaching of the topic heat (thermodynamics) was maintained in the IBD programme, by means of a section of largely mathematical and traditional physics theory. The NSW Board of Studies (BOS), on the other hand, had replaced this topic in the HSC syllabus by introducing a large section of new, non-traditional content.

This new content includes the theory of relativity taught within the context of space travel as well as the historical development of scientific ideas over the past 125 years. In addition, the new content extended recent theory and discovery in an option topic on nuclear physics entitled 'From Quanta to Quarks'. The syllabus designers included these new topics to make the subject more attractive to students (Board of Studies, 1999; Butler, 2008). The IBD included some of these more current topics such as, History and Development of Physics and Relativity as option topics rather than within the physics core.

Table 4.4: Comparing Topics Covered by the HSC and IBD Physics Syllabus Using the Dewey decimal classification

Prime Divisions	Dewey decimal	Topic	HSC	IBD
I	530.11 530.12-18	Relativity, mass and energy, Wave motion	√ √	√ √
II	531.11-531.82	Mechanics	√	√
III	532.11-532.72	Hydrostatics 1		
IV	533.41-533.42	Hydrostatics 2		
V	534.11-534.81	Sound	√	√
VI	535.11-535.86	Light	√	√
VII	536.21-536.81	Heat		√
VIII	537.11-537.74	Electricity	√	√
IX	538.11-538.71	Magnetism	√	√
X	539.11-539.16	Electrons and structure of matter	√	√
II	530.8	Testing and measurement	√	√
XI	539.2-539.7	Radiation-Atomic and nuclear	√	√

4.2.3 Physics Topics Depth and Breadth

A more in-depth study of the syllabus and associated curriculum documents indicated that, whilst there was little difference between the HSC and IBD in terms of the topics taught, there was a difference in the depth and breadth to which the subjects are included. To ascertain a measure of depth, the difficulty of the mathematical content required and the level of scientific language expected was examined. This involved comparing the mathematical demands, technical skills and terminology used within the syllabus documents and examination questions. Syllabus documents and examination questions were examined to provide an indication of the level of mathematical content and scientific language required.

In general, the HSC content was found to be broad across each topic division, with limited mathematical depth. Most of the exercises required the substitution of figures into equations that were already provided. The content also incorporated a general underpinning of historical and social context for each of the physics concepts studied. For example, an HSC student was expected to be able to "Identify data sources, gather, analyse and present information on the contribution of one of the following [6 scientists] to the development of space exploration" (Board of Studies, 2002a, p. 42). Further, the students were asked to "Compare qualitatively low Earth and geo-stationary orbits. Define the term orbital velocity and the qualitative and quantitative relationship between … using Kepler's law of periods. Solve problems and analyse information using Kepler's equation" (Board of Studies, 2002a, p. 42). It is noticeable that the key verbs were descriptive – identify, compare, with the only mathematical or analytical verb being 'solve'.

In contrast, the content of the IBD was found to be more traditional, and appeared to be more mathematically based. Exercises included in the programme required the derivation of physical relationships as well as the application of equations. For example, with respect to teaching and learning orbital motion within the syllabus, IBD students were expected to "State Kepler's third law: the law of periods. Derive Kepler's third law. Derive expressions for the kinetic, potential and total energy of an orbiting satellite. Draw graphs …" (International Baccalaureate Organisation, 2001,

p. 66). The student was expected to derive the two equations as well to apply and to solve them in different situations and analyse data graphically.

This pattern was continued throughout the two physics courses. It would appear that, in this respect, students studying the HSC were likely to be skilled in scientific literacy but may lack the mathematics underpinning more complex physics.

One of the compulsory core activities of the IBD, the Theory of Knowledge (TOK) would appear to add breadth to the physics content that was not included in the HSC. The Theory of Knowledge unit covered some historical and social scientific thinking. An example of this was provided in one of the questions posed in the syllabus document in the Natural Science section: “How does the social context of scientific work affect the methods and findings of science?” (International Baccalaureate Organisation, 2003, p. 20).

Both the IBD and HSC included options that cover relatively recent advances in the fields of medicine and astrophysics, giving students an opportunity to understand the importance and wider application of physics theory. Again, the IBD option topics tended to be more mathematically based than the HSC option topics which tended to be more descriptive.

This section on examining and comparing the physics syllabi indicated that although there were many similarities in the physics topics, the nature if the two courses were quite different. The IBD subject content was more traditional in both the subjects studied and the mathematical underpinning of all topics. The HSC programme, on the other hand, provided a more contemporary focus, in which topics were based in both history and contexts, with less mathematical underpinning required.

4.3 AIMS AND OBJECTIVES

In the past thirty years science curriculum innovation, across developed countries, have shifted from a more traditional, separate discipline approach to an approach that provides a more integrated and holistic experience for the student (Fensham, 1992; Wallace & Louden, 1998; Australian Council for Educational Research, 2001;

Conley, 2003; Walker, 2005). This is particularly evident in the HSC curricula, which frequently required the subject content to be embedded within skills and contexts rather than vice versa. Halls' model (1971) for syllabus analyses not only includes the subject knowledge for the physics course, but also what he calls 'skills and predispositions'. These concepts were covered in the aims and objectives sections of both the HSC and IBD programmes. It was appropriate, therefore, to use Halls' model again for this aspect of the present curriculum comparison. This section examines the aims (Section 4.3.1) and objectives (Section 4.3.2) included in each of the curriculum documents.

4.3.1 Comparing the Aims of the Physics Syllabi

To help to compare the aims of the two courses, Hall's model (1971) was extended by including a numbering system, or scale, to indicate the extent to which the syllabus for each programme covered each aim. This method assumes that the emphasis that a programme places on an aim is reflected in the number of references to that aim in its syllabus content. The scale ranged from 0 to 3 in which 0 indicated that there were no references to an aim, 1 indicated up to two references to an aim, 2 indicated up to four references to an aim and 3 indicated up to six references to an aim. This comparison is shown in Table 4.5, where the aims of teaching physics are listed in the first column, and the number of references to that aim, indicated by the scale, is listed in the second and third columns.

The IBD programme guide (International Baccalaureate Organisation, 2004) listed ten aims of the Group 4 Experimental Science subjects (of which physics is one). These aims corresponded reasonably well with the framework model developed by Halls (1971), although two aims were not included, these being: the recognition of the need for collaboration (IBD Aim 5), and the requirement of information technology (IBD Aim 7). In contrast, the HSC's Board of Studies Physics Stage 6 Syllabus booklet identified three aims, all of which match well with Halls' model.

Six of the aims listed in Table 4.5 can be considered to be traditional aims of a science course these being: Knowledge of laws and phenomena based on observation and experiment (Aim 1), A comprehensive view of nature (Aim 2), The acquisition and understanding of the scientific method (mode of thinking, manner of observing and reasoning) (Aim 4), Ability to reason, analyse, development of imagination and judgment (Aim 5), Written work: logical order, correct expression (using language and symbolism of science) (Aim 6), and Limitations of physics (provisional nature of hypotheses) (Aim 11). All six of these aims were featured in the course intentions of both science programmes.

Table 4.5: A Comparison of the Aims of the HSC and IBD Physics Syllabi.

	Aim of physics teaching	Number of References	
		HSC	IBD
1.	Knowledge of laws and phenomena based on observation and experiment.	3	2
2.	A comprehensive view of nature.	1	1
3.	Technical applications of physics in economics and daily life.	3	1
4.	The acquisition and understanding of the scientific method (mode of thinking, manner of observing and reasoning).	2	2
5.	Ability to reason, analyse. Development of imagination and judgment.	2	2
6.	Written work: logical order, correct expression (using language and symbolism of science).	2	2
7.	Coherence and other subjects, e.g., mathematics, economics, technology.	1	3
8.	History of physical thinking.	3	1
9.	Humanist element of history of physics (scientists).	3	1
10.	Character and moral training.	1	1
11.	Limitations of physics (provisional nature of hypotheses).	2	1
12.	Philosophical aspects.	0	0

During the analysis, a pattern emerged, in which aims that were considered to be more contextually and historically based were referred to more frequently in the HSC syllabus than the IBD syllabus (3:9). These aims included, Technical applications of physics in economics and daily life (Aim 3), History of physical thinking (Aim 8) and Humanist element of history of physics (scientists) (Aim 9). For example, throughout the IBD topic Electricity and Magnetism, no scientists were mentioned and only one application (the motor) was mentioned. However, in an equivalent HSC topic, Electrical Energy in the Home, specific reference was made to two scientists, their hypotheses, and eight applications. This example emphasises the more contextual and social nature of the HSC syllabus. It would appear that, in this respect, the HSC aspired to a more contemporary focus than the IBD.

The IBD syllabus referred more frequently to aims that would appear to be more mathematically based than the HSC syllabus (3:1). These aims include Aim 7, Coherence and other subjects, e.g., mathematics, economics, technology. This could indicate that the HSC physics syllabus tended not to target traditional scientific knowledge to the same extent as the IBD. The more traditional/mathematical approach of the IBD could reflect its international nature and its necessity for conformity within the variety of contexts featured by its member schools.

Both syllabus documents referred indirectly to the aim, Character and moral training, through concern with ethical issues involved in science (Aim 10). Neither syllabus documents, in either course, referred to the aim Philosophical aspects (Aim 12), although the IBD did cover this aim within its cross-curricular Theory of Knowledge unit.

4.3.2 Comparing the Objectives of the Two Syllabi

The objectives of the two physics courses were compared using the main syllabus documents. The IBD physics syllabus included five science objectives that were to be addressed. The first three were divided into short statements linked to a list of clearly defined action verbs that indicated the depth of treatment required. For example, "Demonstrate an understanding of … scientific terminology" (International Baccalaureate Organisation, 2001, p. 7). Students were encouraged to familiarise themselves with the definitions of these verbs as they were told that they would be included in examination questions. The final two objectives referred to the demonstration of personal skills and manipulative skills to be attained.

The objectives of the HSC science course, on the other hand, were divided into two sections with fifteen objectives. The first ten objectives were linked closely to course content and aimed to focus the development of student knowledge and understanding in these areas. For example, "Students will develop knowledge and understanding of the history of physics" (Board of Studies, 2002a, p. 8). The final five objectives involved developing skills in the scientific field, leading to further development of those skills gained in the Year 10 science course. For example, "Students will develop further skills in planning investigations" (Board of Studies, 2002a, p. 8). Although not mentioned in the syllabus document, the individual study items in the syllabus content were led by action verbs similar to those clearly identified in the IBD guidelines. The external examination questions were also based on these verbs. The BOS supplied a list of these verbs and their required meaning on its website (Board of Studies, 2002a).

In 1999, the BOS delivered outcomes based curricula for all subjects and all levels. The HSC syllabus extended the course objectives with matching outcomes to be addressed at both the preliminary and HSC level. These course objectives were divided into three areas, these being, contexts (intended to increase the motivation, scientific literacy and confidence of the students), prescribed focus areas (to help to identify the required emphasis of a topic area), and domains (to illustrate the area of knowledge and understanding, with the skills, values and attitudes to be learned). The objectives and outcomes were clearly tabulated in the syllabus document (Board of Studies, 2002a) to provide an overview and to indicate the related progression from the preliminary level to the HSC level. Key competencies were also identified as being embedded within the syllabus. The IBD physics syllabus did not mention these aforementioned categories, but rather, the requirements for each topic to be studied were stated explicitly (International Baccalaureate Organisation, 2001).

4.3.3 Comparing the Skills to be Included in the Teaching of Physics

Since the 1960s, scientific skills have been identified as an important aspect of science teaching. More recently, however, skills have been linked to everyday applications including the ability to make judgements (Goodrum, Hackling & Rennie, 2000). In 1999, the Australian Council for Educational Research identified eighteen skills necessary for successful university graduates (Australian Council for Educational Research, 2001). Many of these skills were considered necessary to prepare students for university education. This section compares the skills stipulated in each of the two physics courses using Gilbert's (2004) model that was based on the Australian Council for Educational Research (2001), to compare programmes in

Queensland. The eighteen generic skill categories identified by the Australian Council for Educational Research model are listed in Table 4.6 and were used to help to compare the two science curricula. This section describes the modifications made to the model to ensure its suitability to the present study. The section then goes on to discuss the frequency with which the various skills occur in each syllabus document.

Modifications Made to the Model

Many of the Australian Council for Educational Research (2001) skills were not mentioned directly in either the IBD or HSC core syllabus, but were referred to in wider documents as underpinning skills. These have been marked with an asterisk (*) in Table 4.6 and include Critical thinking (Skill 4), Logical reasoning (Skill 5), Ethics/citizenship/social-responsibility/empathy (Skill 6), Interpersonal skills/teamwork/leadership (Skill 8), and Confidence/self-reliance/initiative (Skill 10). Generic skills mentioned only within the IBD wider documents were Flexibility/tolerate uncertainty (Skill 10), Personal skill/self-management/reflective (Skill 15), and Global/historical perspective (Skill 17). Generic skills mentioned only within the HSC wider documents and not in the IBD documents were the Creativity (Skill 7) and Cross-cultural perspective (Skill 17).

The IBD document guidelines used a wider variety of terms to describe different skills compared to the HSC documents. Therefore, to be more inclusive of inferred skills and to give a more accurate analysis, some of the terms were expanded. For example, in addressing Skill 1, Communication, structured Response, the verbs chosen to fit this skill from the HSC key verb list (referred to in Section 4.2) included describe, explain, distinguish and discuss. The syllabus document was then examined for these verbs.

The task of identifying the skills within the documents was not as straightforward as it first appeared. For example, there were cases where skills, such as Creativity (Skill 7), were not mentioned in the IBD physics document, but was implicit within the Group 4 Experimental Sciences project, one of the stipulated assessment tasks which all science students must complete.

Table 4.6: A Comparison of the Frequency with Which Specific Skills are Documented in the Core IBD and HSC syllabus

	Skills	Frequency of Mentions in Core Syllabus	
		HSC Physics	IBD Physics
1.	Communication/structured written response	117	59
2.	Problem solving/applied reasoning	22	26
3.	Analytical skills	40	11
4.	Critical thinking	11*	2*
5.	Logical reasoning	2*	9*
6.	Ethics/citizenship/social responsibility/empathy	3*	5*
7.	Creativity	1*	0
8.	Interpersonal skills/teamwork/leadership	1*	6*
9.	Sceptical but open-minded	0	0
10.	Flexibility/tolerate uncertainty	1	3*
11.	Capacity for or commitment to lifelong/independent learning	0	0
12.	Numeracy/ability to quantify	9	6
13.	Literacy	0	0
14.	IT familiarity/IT use	14	Separate section
15.	Personal skills/self-management/reflective	0	12*
16.	Confidence/self-reliance/initiative	1*	2*
17.	Global/national/historical/cross-cultural perspective		
	▪ Global	0	1*
	▪ National	6	0
	▪ Historical	6	1*
	▪ Cross-cultural	1* (Aboriginal)	1*
18.	Information literacy/management/research skills	Within every outcome >300	3*

* Data not directly referred to in syllabus but referred to in other curriculum documents

Skill 17, Global/national/historical/cross-cultural perspective, condenses a diverse set of skills into one group. To help to identify the diversity of the skills required within two programmes it was decided that each aspect would be assessed separately as Global, National, Historical and Cross-cultural Perspectives. The Global Perspective was initially interpreted as the scope of world-wide current scientific advancement. However, the IBD physics syllabus document placed a different perspective by specifically recommending the correspondence of students between IBO schools worldwide using email, hence incorporating ICT skills. To address this, a broader interpretation of the skill was adopted.

Frequency with Which a Skill is Reported

This section examines the frequency with which each of the skills were reported in the core physics syllabus documents and how the relative emphasis placed on the different skills was influenced by each curriculum. The frequency with which each syllabus document refers to a skill are reported in Table 4.6.

For the HSC syllabus, the skill most referred to (more than 300 times) in the HSC document was Information Literacy/Management/Research (Skill 18). This high score indicated the strong emphasis on scientific literacy included in this HSC course. The recent Australian government guidelines for the need to improve scientific literacy (Goodrum, Hacking & Rennie, 2000) could have influenced this high number of references. In contrast, the IBD syllabus appeared to provide the teacher with more autonomy of specific teaching and learning activities, however, there were a few references to information literacy or research skills and no reference to scientific literacy.

The skill most frequently referred to in the IBD physics syllabus (59 times) was Communication/Structured Written Response (Skill 1). This skill was also referred to frequently (117 times) in the HSC physics syllabus. This number of references indicated a strong emphasis on literacy skills demanded in both the IBD and HSC physics course. Interestingly, however, neither the IBD or HSC syllabus documents referred specifically to Literacy (Skill 13), a term referred to in the Australian government guidelines (Goodrum, Hacking & Rennie, 2000).

Four of the skills, Problem solving/applied reasoning (Skill 2), Analytical skills (Skill 3), Critical thinking (Skill 4), and Logical reasoning (Skill 5), are all skills needed for science subjects. The skills 4 and 5 were referred to in related support documents but not directly in the syllabus documents of either programme. The number of references indicated that the IBD has a heavier emphasis on Problem solving/applied reasoning (Skill 2), supporting the greater mathematical focus observed earlier. Analytical skills (Skill 3), were emphasised in examination questions but given little overt reference in the IBD syllabus (see Section 4.4.2), The HSC syllabus referred to analytical skills more often (4:1) and demanded analysis in all of the many research tasks throughout the topics.

The phrase Independent Learner (Skill 11) appeared in the overarching framework statement of the HSC science syllabi (Board of Studies, 2002a) but not in the IBD syllabus. It should be noted, however, that although never mentioned in the IBD physics syllabus, independent learning was given high priority in the main programme statements (International Baccalaureate Organisation, 2004). It would appear, therefore, that an intention of both the HSC and IBD programmes was to prepare the students adequately for further education.

The Flexibility/tolerate uncertainty skill (Skill 10) was approached differently by the two programmes. This skill was only mentioned in the overarching Knowledge and Understanding section of the HSC syllabus document, in that "Students are encouraged to develop attitudes … of flexibility … and tolerate uncertainty" (Board of Studies, 2002a, p. 14) and in the assessment section for "flexibility of the design of tasks" (Board of Studies, 2002a, p. 78). However, the IBD syllabus addressed the issue of uncertainty in measurements and collecting data, addressing the concept mathematically, as a valuable scientific skill required for tertiary science.

Interestingly, Initiative (Skill 16) was only mentioned once in the HSC supporting syllabus document, in the context of the compulsory open-ended investigation when it was advised that students "…take the initiative in finding answers to problems … before they can propose a possible answer." (Board of Studies, 2002b, p. 35). However, no mention was found in the IBD documents, only self-reliance. It could be inferred that, at this stage of a student's education, initiative was not seen as an important skill by either curriculum.

With reference to Table 4.6, Information Technology (Skill 14) is now generally known as information and communication technology, and is required to be embedded within each of the programmes. A difference was identified within the two syllabi with regards to how Information and Communication Technology (ICT) was addressed. In the IBD, the guidelines devoted several pages to a breakdown of the suggested uses of ICT, encouraging both its employment and importance (International Baccalaureate Organisation, 2005). The Guide added a codicil, acknowledging the diversity of hardware and software between IBO member schools across the world, and assured that the use of ICT would not be monitored or included in assessment (International Baccalaureate Organisation, 2001). In the HSC documents, however, ICT was embedded throughout the course and suggestions for its use were mentioned in various places throughout each of the topics in the syllabus.

This section has compared the aims, objectives and skills of the two curricula using Halls' model (1971) and Gilbert's model (2004). The results indicated that, although similar in some respects, the aims of the IBD physics course aims tended to develop and focus more on the mathematical requirements than the HSC course, which tended to focus more on the historical and social aspects. It should, however, be noted that a frequency count of topics can reflect a 'political' rather than educational agenda. In NSW the need for this new focus has been in order to attempt to attract more students into choosing science subjects, whereas the IBO is required to meet international tertiary demands. Nevertheless, it was important to examine these differences in order to compare the ways in which these two programs are constructed. These differences influence the attitudes of both students and teachers in the ways they approach science courses. In addition, decision making by students and their parents about which program to take is influenced, at least partly, by the approaches to science taken in the two curricula.

The next section examines and compares the assessment requirements of the respective curricula.

4.4 ASSESSMENT MANDATED BY THE ORGANISING BODIES

The methods used to measure the success of a student participating in a programme can assist in helping teachers to tailor its delivery, thereby influencing the implemented curriculum. Using the HSC and IBD syllabus documents, details of the assessment required by the two organisations were examined and compared. Because the assessment requirements were different for the two levels of IBD it was considered prudent to examine both the Standard Level and the Higher Level IBD programmes. The following two sections are devoted to describing and comparing the internal assessment format (Section 4.4.1) and the external assessment format (Section 4.4.2) for each of the programmes.

4.4.1 Internal Assessment Format

Although there were many similarities, there were some fundamental differences between the internal assessment formats between the two programmes. This section provides details about the internal assessment format for each of the two science programmes.

For assessment purposes, the HSC was divided into two years. The first year, or preliminary course, was internally assessed at the end of three terms. Passing the preliminary course was recommended but not compulsory. Only the second year of the HSC course was assessed for grading purposes, including both an internal and external assessment component. In contrast, the IBD science course was run over two years but only the practical component of the internally assessed coursework contributed towards grading, alongside the final external examination score.

The internal assessment tasks for the IBD and HSC programmes were different in nature and weighting, with the HSC programme having a more varied internal assessment than the IBD. The HSC internal assessments were expected to be tailored to meet selected outcomes in the syllabus and were weighted to meet the recommendations laid out by the BOS in the syllabus documents. The HSC syllabus suggested that teachers use a range of assessment instruments, such as assignments and open-ended investigations. The experiments that must be covered within the practical component were listed in the syllabus of the HSC and often included in the external examination. The internal assessment counted towards half of the student's final mark. The BOS stipulated that a maximum of 50% weighting of the internal assessment was by written examination and a minimum of 30% was allocated to first-hand investigations and their analysis (see Table 4.7). Teachers were expected to submit the final percentage grade for the internal assessment to BOS together with the ranking of the student in the subject cohort. The BOS then used the moderate to the internal assessment grade with the final examination grade to give a final grade (Board of Studies, 2002b).

Table 4.7: Comparing Assessment for Course Completion and Grading

Course	IBD Standard Level (SL)	IBD Higher Level (HL)	HSC
Length	2 years	2 years	1 year (+ preliminary)
Study hours	150	240 (150+90)	120 (+120)
Internal task	Practical work	Practical work	Range of tasks - including written exams ≤25%
Weighting	24%	24%	50%
Time	55 hours	81 hours	Not specified
External task	3 exams	3 exams	1 exam
Weighting	76%	76%	50%
Time	3 hours	3 ½ hours	3 hours
Total assessment	100%	100%	100%

Unlike the HSC, the internal assessment for the IBD had no examination component. The internal assessment requirements for the IBD were centred mainly on the assessment of practical skills. All IBD teachers were provided with a marking grid, which enabled them to record students' marks as they completed the required skills and content. Each student was assessed internally, at least twice, on each of eight practical assessment criteria to give a final mark out of 48. This was then scaled at the International Baccalaureate Curriculum and Assessment Centre to give a total assessment out of 24%.

The IBD also required what is called a 'Group 4 Project'. This project was intended to be a collaborative experience involving all of the Experimental Science students. The project was designed to help students to appreciate environmental, social and ethical implications encountered during the study of science. Further, this aspect of the assessment was intended to contribute to the holistic nature of the programme (International Baccalaureate Organisation, 2001). The project was allocated 10-15 hours of the internal assessment period and was expected to be designed, implemented and evaluated by the students under the guidance of the teacher. Grades for this project did not contribute towards the internal assessment marks, but could be used to contribute towards the practical work mark at the teacher's discretion. In all cases, the IBO required a sample of the project from the school as evidence of a candidate's involvement and to indicate the overall standard of the school.

In summary, there were a number of differences between the internal assessment requirements for the HSC and IBD programmes. HSC teachers were expected to design their own internal assessment tasks, and to select the knowledge and skills to be tested internally. However, they were directed by the syllabus to stipulated laboratory activities that could be examined at the end of the year. In contrast, the IBD required only the assessment of practical skills and teachers were expected to select their own laboratory activities.

The weighting allocated to the HSC internal assessment (50%) was twice that of the IBD internal assessment (24%). This formative assessment enabled an HSC student to build on their abilities throughout the year as there was less emphasis on the final external examination. In contrast, the IBD students had the larger summative assessment component (76%), and hence greater emphasis, on their final external examination. The examination component for each programme is examined in the next section.

4.4.2 External Examination Format

A student's final grade will often dictate his/her future in terms of further education. As a consequence, the external examination content will have a strong influence on the delivery of the programme and holds great significance for students and staff alike. Because of the importance placed on the final examination (75% of the final score for the IBD, and 50% of the final score for the HSC) it was considered important to compare the format of both. This section describes the format and structure of the two examinations, as outlined in the IBD and HSC physics course documents. The section then goes on to describe and compare the nature of the questions included in past examination papers in each of the programmes.

Format and Structure of the Examinations

The first major difference between the two examination papers reflected the international flavour of the IBD examination. For the IBD, students were able to sit the examinations in Spanish or English, whereas the HSC was available only in English.

External assessment for both the IBD and HSC used written examinations only. For the HSC students, the final examination made up 50% of the total mark and was based on content taught during the second year (120 hours of teaching). These students sat one, three hour examination, which was comprised of three distinct sections. For the IBD students, the external examinations made up 75% of a student's final mark and were based on the content taught over two years of study (150 hours of teaching at the Standard Level and 240 hours of teaching at the Higher Level). The IBD students sat three shorter examination papers, the combined length which was three hours for the Standard Level and five hours for the Higher Level. Table 4.8 provides a summary of the external assessment examination specifications for each of the programmes.

This section describes, in turn, the three IBD examination papers and the HSC examination paper, and then compares the two. For both the Standard Level and Higher Level, the IBD examination papers followed a similar format and had similar weightings, but students enrolled at the Higher Level were required to have a higher level of understanding.

The first IBD examination paper contained only multiple choice questions, of which 15 were common to both level papers. The examination paper for students enrolled in the higher level course had five additional, more difficult questions related to core topics and twenty questions related to the Higher Level investigation work.

The second IBD examination paper was comprised of one question that required the manipulation and analysis of data in addition to compulsory short-answer questions based on the core topics. These questions were followed by three extended response questions, also based on the core topics, of which students selected one. Students studying the Higher Level course were required to answer a further two questions (selected from four alternatives) based on the core and Higher Level content.

Table 4.8: Comparing External Assessment Examination Specifications

Paper/ Section	Assessment specifications	IBD (Standard Level)	IBD (Higher Level)	HSC
1	Overall weighting (%)	20	20	7½
	Duration (hours)	¾	1	Allow ½
	Format	30 multiple choice	40 multiple choice Plus 20 related to HL	15 multiple choice
	Syllabus	Core	Core and HL	Core
2	Overall weighting (%)	32	36	30
	Duration (hours)	1¼	2¼	Allow 1¾
	Format	Several short answer 1 extended response (choice)	Several short answer 2 extended response (choice)	Several short answer and extended responses
	Syllabus	Core	Core and HL	Core
3	Overall weighting (%)	24	20	12½
	Duration (hours)	1	1¼	¾
	Format	Several short answer	Several short answer 1 extended response	Several short answer 1 extended response
	Syllabus	Options (2)	Options (2)	Option (1)
Total	Total duration (hours)	3	5	3
	Total weighting %	76	76	50

The third IBD examination paper involved questions related to the two option topics (selected by the teacher) that students had studied during the year. The examination paper was comprised of both short and extended response questions on each of the topic, demanding a satisfactory level of scientific literacy within the answer. See Table 4.8 for a summary of the external assessment specifications for each of these papers.

The three-hour HSC examination, taken at the end of the second year, was divided into three sections, each of which bore some similarity to the three examination papers sat by the IBD students. The first section of the HSC examination was similar to the first examination paper sat by the IBD students. This section was comprised of 20 multiple choice questions that varied in difficulty and style.

The second section of the HSC examination paper was similar to the second IBD examination paper in that it involved both short and extended response questions that required the students to draw on a range of skills and content knowledge from the core syllabus. Unlike the IBD examination paper, however, there were no alternatives from which the students could select. This section of the HSC examination carried a weighting of 60% of the paper (as opposed to less than 50% for the equivalent IBD examination paper).

The third section of the HSC examination included both short and extended response questions based on the option topic studied by the HSC students during the year. Unlike the IBD students who studied two options, the HSC students studied one option. Consequently these students were recommended to allocate less time to this section. This section, as with the third IBD examination paper, demanded a good level of scientific literacy within the answer. Unlike the IBD examination, the HSC questions were allocated a level of difficulty to enable students, from the full range of abilities, to demonstrate their achievement.

There were several interesting points arising from the comparison of the examination papers. First, IBD Higher Level students had an extra 66% of examination time (5 hours compared with 3 hours), in which to test twice the work content of the HSC students (240 hours versus 120 hours). However, for the Higher Level IBD students this only accounted for 26% extra weighting within the final assessment score. The Standard Level examination was comparable to the HSC in duration, but tested 25% more work content for 26% extra weighting.

Second, the multiple choice questions were given considerably more value, almost twice as much in the IBD examination compared to the HSC examination. The situation was somewhat reversed, however, for the second IBD examination paper and the second section on the HSC paper with the short answer questions.

Third, more emphasis was placed on the IBD third examination paper (option topic) than in the third section in the HSC examination (option topic). Although, as indicated by Table 4.2, the teaching hours allocated were the same for the Standard

Level and HSC students (30 hours) the weighting for the IBD option paper was 50% greater than for the HSC option section in the external examination.

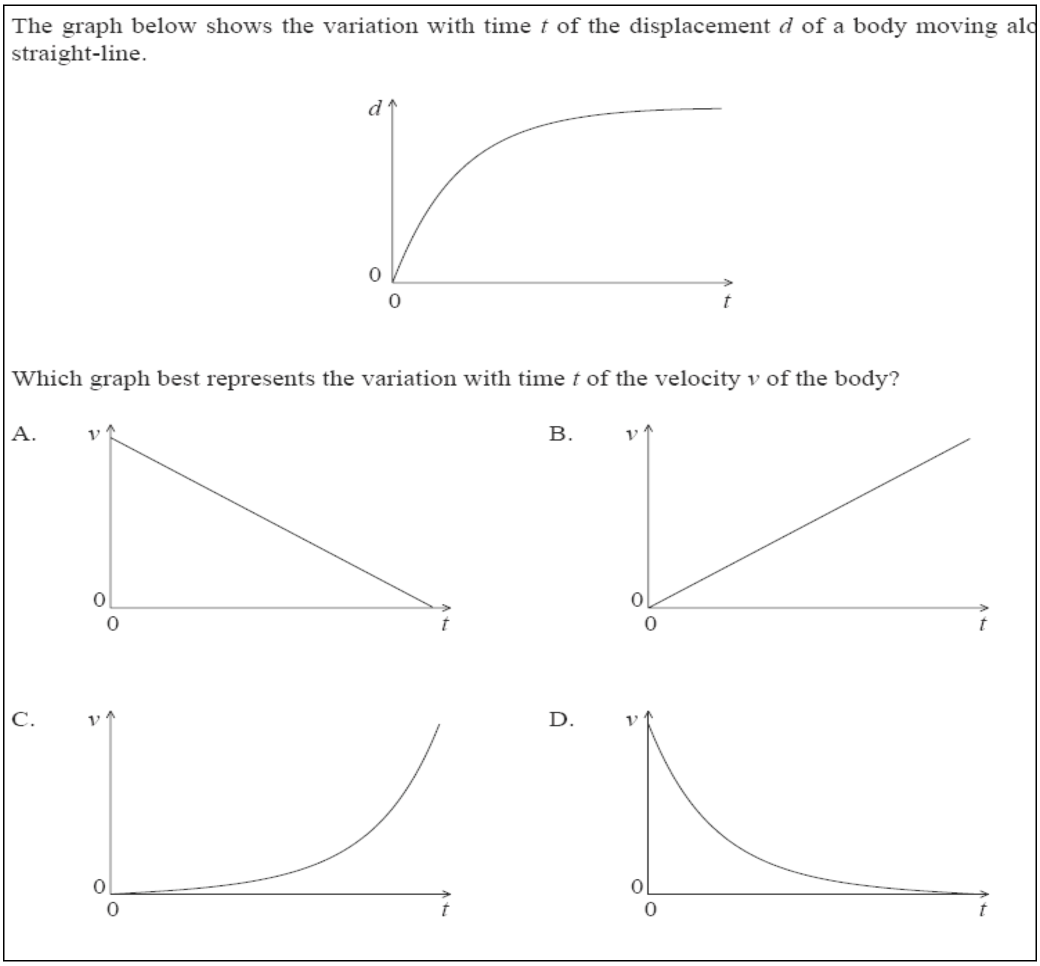
Finally, with respect to technology, the IBD did not permit the use of calculators in the first examination, but did allow the use of a programmable graphic display calculator in the other two examination papers. The HSC, on the other hand, allowed stipulated models of scientific but not programmable calculators to be used throughout the examination.

Comparison of Sample Questions

To compare the examination questions used in the IBD and HSC external examinations careful selection of the questions ensured that similar style questions within a similar topic were selected for analysis (both were selected from 2006 physics examination papers). To this end, a multiple choice and an extended response question were selected within the topic of dynamics. The first IBD examination paper and the first section of the HSC examination included multiple choice questions.

For the multiple choice question, the Higher Level IBD examination paper required students to translate information from a graph into an activity that involved a body moving a certain distance in a set time. (See Figure 4.3.)

In this example, students were required to analyse the motion to match a graph of the body's velocity during that time. There were four answers from which students could select. To answer this question correctly the student would require an understanding of mathematics (a compulsory subject for the IBD) and would need to be familiar with the shape resulting from integration of the curve of the graph. There was no such linear motion question that was equivalent in nature in the Standard Level examination paper.


The graph below shows the variation with time t of the displacement d of a body moving alc
straight-line.

Which graph best represents the variation with time t of the velocity v of the body?

A. B. C. D.

Figure 4.3: IBD Multiple Choice Question (Excerpt from IBD, November 2006 Advanced Level Paper Examination, International Baccalaureate Organisation, 2006)

The HSC examination had a question that was similar in nature. The question in Figure 4.4 described the scenario of throwing a stone from a cliff onto a beach below.

The HSC student was required to select, from four graphs the one that best described the motion. To answer this question correctly the student would need to understand parabolic motion, be aware that acceleration only occurs in the vertical component of the motion and that it is constant. The two questions, though similar in topic and concept, require quite different skill levels. The level of mathematical skill (analysis and graphing) required by the IBD students was higher, whereas the HSC question required understanding of a more complex motion and extended knowledge.

A stone is thrown horizontally from the top of a cliff and falls onto the beach below.

Which acceleration–time graph best describes the motion of the stone?

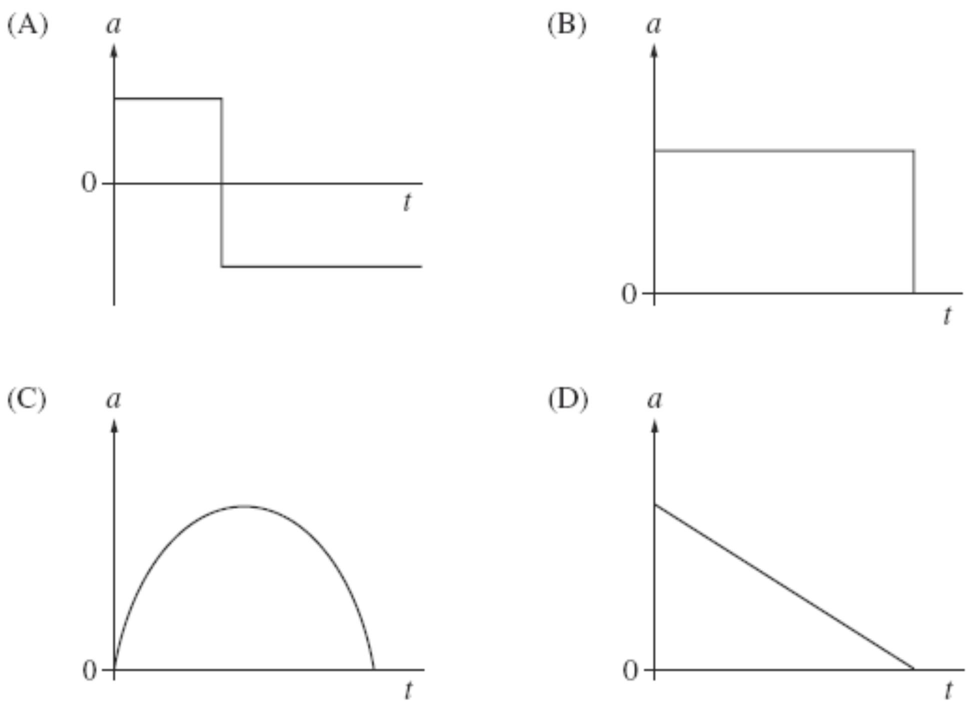


Figure 4.4 HSC Multiple Choice Question (Excerpt from the HSC, October 2006 examination paper, Section 1, Board of Studies, 2006).

The second question that was compared was selected from the extended response questions in the second paper for the IBD examination and the second section of the HSC examination. In the IBD examination paper this question was worth 25 marks out of a total of 95 marks for the paper, and involved twelve parts. In this respect, it was the topic that was extended within the question rather than the response. The complexity of the answer was increased somewhat in this question when compared to the multiple choice questions.

The selected part of the IBD question to be compared with the HSC question (worth four of the 25 marks) required an understanding of the context within which the wider question was set, and then manipulation of given data in order to apply the set verb from the IBD syllabus to ‘determine’ a temperature rise (see Figure 4.5).

(f) Calculate the escape speed for a spherical planet of radius 1.7×10^{3} km having an acceleration of free fall at its surface of $1.6\,\mathrm{m\,s^{-2}}$. *[2]*

(g) The mean kinetic energy E_K, in joule, of helium-4 atoms at thermodynamic temperature T is given by the expression

$$E_K = 2.1\times10^{-23}\,T.$$

Determine the surface temperature of the planet such that helium-4 atoms on the surface of the planet have the escape speed calculated in (f). *[2]*

(h) Suggest **one** reason why, at temperatures below that calculated in (g), helium will escape from the planet. *[1]*

Figure 4.5 IBD Extended Response Question (*Excerpt from the IBD, November 2006 Advanced Level Paper 2 examination,* International Baccalaureate Organisation, 2006).

In contrast, for the extended response question in the HSC examination paper, the content stood alone from that topic section. That is, unlike the IBD question, there was no related question that served as an introduction. The section of the question chosen for comparison, worth six of the 25 marks, involved a one sentence scenario and required the verb 'analyse' to be applied to the forces in the scenario.

Twelve lines were printed for the student's written response and these were intended to indicate the length of response required. Space was also a provided for a diagram.

Question 17 (6 marks)

Parts of a space mission involve a spacecraft spending time in geostationary orbit, and then returning safely to Earth.

Analyse the forces acting on this spacecraft during these parts of the mission.

Figure 4.6 HSC Extended Response Question (*Excerpt from the HSC, October 2006 Examination Paper, Section 1,* Board of Studies, 2006).

The extended answer questions in both the HSC examination and the IBD examination required students to understand the theory and context within which the question was set. The HSC examination question required a high level of scientific literacy and memory skills to achieve the full six marks. The lack of structure and high level of scientific literacy needed can prove challenging for students. In contrast, the IBD examination question provided more structure for students and required more mathematical skill than did the HSC examination question. This structure guided the students, enabling them to demonstrate deeper understanding and application of the complex mathematical skills required by the syllabus as well as testing memory skills. This reflected the depth of the IBD physics course and the breadth of the HSC physics course that was identified in Section 4.2.3. However, neither of these questions could be said to extend the students by presenting an opportunity to apply conceptual knowledge that they might have gained.

Further analysis of the two papers revealed a repetition of these themes, with the IBD examination papers testing a wide range of mathematics applications and the HSC examination papers requiring a higher level of scientific literacy to be demonstrated in order to achieve top marks. There was also a stronger emphasis on stating and defining facts in the IBD examination papers than in the HSC examination papers.

Both assessment procedures have been criticised by educational analysts both in the U.S. (National Research Council, 2002) and in NSW. The IBD science examinations have been criticised by the National Research Council as memory tests that "assess the acquisition and retention of information as distinct from understanding, applications and extensions of concepts" (National Research Council, 2002, p. 269). The National Research Council (2002) also accused the examination papers of not addressing higher level skills.

With respect to the HSC, teachers across the State, meeting at the HSC marking centres, Science Teacher Association meetings and physics teacher workshops have raised concerns, about the layout of the paper and the complexity of the questions. It has also been questioned whether the spaces, provided within the examination paper, allow adequate room for students to respond to the answers in sufficient detail. Over the past few years, the nature of the questions included in the HSC has changed. Questions are no longer related directly to syllabus points but are now a more complex integration of the prescribed focus areas. Teachers feel that this type of question can leave students unsure of the depth of response required. In some cases, it was felt that students' lack the skills to 'unpack' the question and thereby demonstrate the knowledge that they possess.

In summary, the emphases of the examination questions within the two papers appeared to be quite different, in both structure and content. The IBD questions involved many sections exploring extended knowledge within a few selected topics and requiring mainly mathematical reasoning. The HSC examination, on the other hand, involved short questions, covering a wide range of topics, and requiring the demonstration of skills in scientific literacy. Both programmes required a high level of understanding of physics but each has addressed assessing students' understanding from a different perspective; the IBD with a traditional mathematical approach and the HSC with a focus on scientific literacy.

4.4.3 Marking Procedures

The marking procedures required in a curriculum has the potential to influence a teachers' informal and formal assessment. The international nature of the IBD meant that the process was quite different from the HSC in several ways. When teaching a curriculum, teachers need to be fully conversant with the mechanisms and significance of the marking requirements to ensure that students' are adequately prepared. In this way, teachers can provide the knowledge required to ensure that students have confidence in the process. Analyses of the relevant documents, my experience as an HSC examination marker and the knowledge of the IBD coordinator, revealed that the marking procedures used by the two curriculum bodies, although different, were in keeping with the nature of each programme. This section describes the marking procedures for both internal and external assessments for the IBD and the HSC.

The IBO was an internationally based organisation with schools situated around the world. To ensure consistency and moderation of marking, the organisation had put into place some requirements that help to ensure that marking was equitable. With respect to the internal assessment, the internationally based IBO, required that the results of the practical assessment (a formal requirement) be recorded on forms. These, in addition to samples of the Group 4 projects (see section 4.4.1) were sent to a central location in Wales, in the United Kingdom for moderation purposes.

In terms of external assessment, the three examination papers were packaged by the school and posted overseas to designated subject markers appointed by the IBO. The IBD papers were then sent off to a second marker, and the marks were submitted centrally to the International Baccalaureate Curriculum and Assessment Centre in the UK. The school's science marks were moderated with the Group 4 project and the final grades allocated a rank from one to seven.

In contrast, the internal and external assessment of the local HSC was coordinated centrally by the BOS in Sydney. Once the marks from the internal (school-based) assessment tasks had been appropriately weighted by the subject teacher, these grades were submitted as a percentage prior to the final examination. The ranking of the students by the teacher defined the student's final position in their school cohort when the external examination marks were awarded. For example, a student ranked fifth in the school cohort will receive the fifth examination mark. A final result was then calculated from that mark combined with their internal assessment mark.

After the final examination the HSC papers were sent to a central location in Sydney. Experienced subject teachers, placed in marking teams, were responsible for the marking of one, or part of one question. The marking teams used HSC marking schemes, drawn up at the marking centre by senior markers. Markers discussed and became conversant with the marking schemes and requirements and agreed rubrics were followed during the marking process.

Papers were initially double marked to ensure the consistency of the marking, and later spot checked. Marks were entered onto a computer-read sheet, compiled and moderated with the school-based assessment marks before a final grade (between one and six) and a percentage mark was given. The school-based ranking of each student was maintained.

The differences between the marking procedures reflected the diverse nature of the programmes. The international nature of the IBD required isolated, individual markers who followed set schemes and then centralised collection and moderation. However the local nature of the HSC programme centralised marking enabled a more collaborative experience to take place followed by moderation final grading.

There was a great diversity in the schools delivering the IBD worldwide, reflected in the wide dissemination of papers and markers. In contrast, there was a parochial nature to the NSW schools delivering the HSC, where the markers were local and collected together in one venue.

4.5 CHAPTER SUMMARY

This chapter reports a comparison of the intended IBD and HSC science curricula in terms of course structures and procedures, course contents, aims and objectives and skills. To apply structure to the overview of the two programmes, the key components of Keeve's (2004) model was used. The antecedents for the intended curriculum referred to the country circumstances. In this case, the school was located in Sydney Australia. In Australia, each state has its own curriculum, creating inconsistencies in senior school curricula. A major problem with these inconsistencies is experienced by parents moving interstate. A national curriculum has been viewed as a solution to the problems but, to date, has not been realised. To address these issues, some independent schools, in each state have started to offer the IBD as an alternative to the State curriculum.

As a first step in comparing the two curricula, an overview of the main philosophies and a description of the organising bodies were provided. The organising body of the IBD is the International Baccalaureate Organisation (IBO). The IBO is based in the United Kingdom and has a world-wide network of schools that, in 2007, was teaching over 500,000 students. The primary aim of the IBO is the development of intellectual, personal, emotional and social aspects that will enable a student to live, learn and work in a rapidly changing world. The International Baccalaureate is offered in three components, designed as a continuum of education of which the IBD is the senior school component. The IBD is designed to be a holistic educational experience made up of six academic subject groups that are underpinned by a central core. These components aim to educate and develop the whole student.

The organising body for the HSC is the Board of Studies (BOS) which is located in Sydney, NSW. The BOS is responsible for and governs all aspects of the curriculum but is overseen by the national Department of Education, Science and Technology. Whilst the overall aim of the HSC is to foster the intellectual, social and moral development of the students, the HSC is not considered to be a holistic program as each subject is taught in isolation rather than as part of an integrated scheme.

In the following sections, the structure of the two physics courses, subject content, aims and objectives were examined in detail. Comparing the structure of the two courses revealed similarities in the required teaching hours, and format of the two curricula, enabling the school timetable to easily accommodate both programmes side by side.

Using an adaptation of Halls' (1971) model, comparisons were drawn between the subject content studied within the IBD and HSC programmes using syllabus documents and linking physics topics to the Dewey system (n.d.). The results indicated that although there were many similarities in topics studied in both physics courses, there were also some notable differences. One of the main differences was in the more traditional nature of the IBD physics course, in both topic content and the depth of the mathematical underpinning that was required. In contrast, the HSC physics course addressed substantial traditional content, but replaced some topics with rather more modern physics topics, such as superconductivity. The HSC topics were also taught within historical and social contexts, and required little in the way of supporting mathematical background. It would appear that the IBD physics course had more depth than the HSC physics course, whilst the HSC course provided more breadth of study.

Using Halls' model (1971), the aims and objectives of the subject of physics within the two programmes were compared. These results reinforced the traditional, mathematical approach of the IBD course compared to the more contextual approach of the HSC. On the surface, the aims and objectives appeared similar, but closer scrutiny revealed that there was a more developed mathematical requirement in the IBD physics course aims than the HSC course, which was again more focused on the historical and social aspects of the subject.

As a next step, in-depth analyses of the skills involved in the teaching and learning of physics was made for each curriculum. These skills were identified and then charted, compared and contrasted using Gilbert's (2004) model. It would appear that in both the HSC and IBD programmes, communication skills were considered to be important, alongside the skills of analysis and information technology. The intention to prepare the students adequately for further education was paramount in both curricula despite not being mentioned explicitly in the documents.

Finally, using syllabus support documents, personal experience and examination papers, the assessment demands, processes and procedures were examined. An analysis of the assessment procedures indicated that the IBD students' assessment relied heavily on external assessment (75%) compared to the HSC assessment (50%). The comparison suggested that the IBD assessment was more formative in nature, and permitted the moderation of the standard within their diverse range of international schools.

Samples of examination questions were compared to provide comparison of the teaching and learning expectations in each programme. The main differences were again those of traditional, mathematically based IBD examination questions, compared with the broader, less mathematical HSC examination questions. The HSC examination questions also were more literacy-based as they required full written responses.

Both programmes included the skills specified on Gilbert's (2004) model, which was intended for tertiary students. The results supported the findings that current senior school science syllabi are tailored for tertiary entry purposes as opposed to vocational destinations for students (Australian Council for Educational Research, 2001). Differences between the assessment requirements were also found. The range and mode of assessment tasks for the HSC involved twice the internal assessment of the IBD and a three hour examination based on one year of work. The IBD, on the other hand, included three short examinations based on two years of work. The local BOS collected the markers and papers in one place and closely controlled the whole procedure. However, the International Baccalaureate Organisation relied on an international distribution of papers and markers, finally collating the results at the end of the process.

The following chapter provides the results of the analyses of data related to the implemented and achieved curricula. The views of the participants (teachers and students) are investigated to provide insights into the implemented curriculum and a range of outcomes are examined to compare the achieved curricula. Finally, the chapter examines whether teachers and students viewed the Year 10 programme to adequately prepare students for their selected course of study.

CHAPTER 5

RESULTS: COMPARING THE IMPLEMENTED AND ACHIEVED CURRICULA

The previous chapter reports the findings of a document analysis that compares the intended curricula of the two programmes run consecutively at Blackwood School, the IBD and the HSC. To contextualise the two programmes further, comparisons are made, in this chapter, to examine what takes place as the curricula are implemented. According to Grundy (1987) it is unlikely that the introduction of a new curriculum will start from nothing as teachers and students will already be engaged in curriculum practice that will ultimately influence the implementation of new curriculum. As a first step, the teachers' views of the issues involved in the delivery of the two science curricula are examined. The chapter goes on to report students' perceptions of the laboratory learning environment created within each of the programmes. To examine the achieved curricula, the chapter reports the results for: student outcomes for each of the programmes in terms of their desire to pursue a career in science; their expectations from the senior science programme; and their University Admissions Index (UAI). Finally, concern was raised about the suitability of the Year 10 science course in preparing the students for their senior courses. Hence the adequacy of this Year 10 course was investigated from the perspectives of the teachers and students enrolled in both programmes.

Multiple sources and methods of data collection were used to obtain information for this aspect of the study. Qualitative data were gathered through interviews, discussions and informal meetings with teachers and focus group meetings with the students participating in the two programmes. Quantitative data was collected using surveys administered to the students. Finally, data related to a range of outcomes, pertinent to science education, were examined and compared for both programmes.

This chapter reports the results of my evaluation and comparison of the IBD and HSC science programmes using the following headings and section numbers:

5.1 Antecedents and Context of the Implemented Curricula
5.2 Issues Related to the delivery of IBD and HSC programmes;
5.3 Student Perceptions of the Learning Environment;
5.4 Comparing Student Outcomes**;**
5.5 Adequacy of the Year 10 Preparation for Studying Senior Science; and
5.6 Chapter Summary.

5.1 ANTECEDENTS AND CONTEXT OF THE IMPLEMENTED AND ACHIEVED CURRICULA

This section seeks to contextualise the curriculum in terms of Keeves (2004) model. The second and third rows of Keeves (2004) model (Figure 4.1) were used to help to contextualise the implemented and achieved curricula of the two science programmes at Blackwood School. Table 5.1 amplifies Keeves model and provides a summary of the antecedents (classroom conditions) and contexts (school or classroom) as they applied to the implemented curricula (row two of Keeves model), and the antecedents (characteristics of the students) and contexts (students) of the achieved curricula (row three of Keeves model) of the two science programmes (IBD and HSC).

Table 5.1: Summary of the Antecedents and Context of the IBD and HSC Science Curriculum at Blackwood School Using Keeves' (2004) Framework

Science Programme	Antecedent	Context	Curriculum
Level 2 – Implemented Curricula			
IBD	Well equipped, new laboratories.	Smaller class sizes <10.	Experienced female teachers, first year implementing this syllabus.
HSC	Well equipped, old laboratories.	Larger class sizes >20.	Experienced female teacher, second year implementing this syllabus.
Level 3 – Achieved Curricula			
IBD	Well motivated, mixed ability students.	Females, aged 16-19, some ESL.	Achievement demonstrated by practical in-school laboratory assessment and final examination on all syllabus content.
HSC	Well motivated, mixed ability students.	Females, aged 16-18, some ESL.	Achievement demonstrated by variety of in-school assessments and examination on final years work only.

The next two sections examine the antecedents related to the implementation of the two curricula, particularly the allocation of the resources and the reasons behind students' selection of the programme (Section 5.1.1), as well as the context of each of the curricula in terms of the make-up of the two student groups (Section 5.1.2).

5.1.1 Antecedents – Allocations of Resources and Students' Selection of Programme

As mentioned earlier, Blackwood School was a non-selective, independent girls' school, situated in a suburb of Sydney. This suburb had a relatively high socio-economic standing and, as the school demands high fees, it can be assumed that the students were generally from affluent families.

The high fees enabled the school to provide good classroom facilities and well equipped and serviced laboratories. There was, however, one difference in the resources provided to the two groups, the allocation of the laboratories. The school had six science laboratories, two older, traditionally designed laboratory spaces built in 1960, and four more recent rooms built in the late 1980s to a more flexible plan. Despite aesthetic differences, all laboratories had access to the same equipment and were serviced by the same laboratory technician. The allocation of the laboratories was based on logistical reasons. The smaller, newer laboratories were allocated to the programme with the least students, the IBD science groups, and a larger, older laboratory was allocated to the larger HSC science group.

To attract students to the new programme, the school conducted a number of information and recruitment sessions aimed at encouraging enrolments in the IBD programme. The first was a meeting open to the local community at which an IBO director spoke, introducing the organisation and its role in international education. This was attended by over 300 adults and students. The IBD was sold as an international passport that would provide entrance to any university in the world.

A further information evening, solely for Year 10 students and their parents, enabled more detailed programme information to be disseminated, and an opportunity to introduce the subject teachers. Parents and students also were informed that the IBD involved more academic rigor than the HSC, and was, therefore, a more difficult programme than the HSC. Largely as a result of these sessions, the IBD programme was viewed as exciting, new and innovative, whilst the HSC programme was viewed as familiar and safe.

There is a contrast in the groups of students that chose the IBD and the HSC programme with respect to their expectations and aspirations which reflects, in turn, their abilities. Although enrolment in both the HSC and the IBD programmes were open to all Year 10 students at the school, none of the students who elected to enrol in the IBD programme were from the two lower-ability streamed classes. In contrast, five students who enrolled on the HSC programme were from these lower classes. As the reverse arrow indicates (see Figure 4.1) these student characteristics could affect the classroom dynamics and the classroom management.

5.1.2 Context – Class Size, Age and Cultural Composition

The size of the class can impact on a students' educational experience. In science lessons, class size is particularly relevant as a larger group is likely to create issues related to classroom organisation, equipment availability, reduced teacher/student contact and higher marking loads, all of which can impact on the implemented curriculum. It is possible that larger groups may also result in fewer hands-on experiences and more cramped working conditions. Although care was taken to select classes of similar sizes, student drop-out from the IBD programme meant that there was still a disparity in class size. For students on the IBD programme the science classes were relatively small (less than ten students), compared to the HSC science classes (more than twenty students).

The age range of the students varied slightly between the two groups. On average, students are 17 years of age when they take their HSC examination. However, both of these groups were comprised of overseas students aiming to obtain access to a Western university. Such students often spend a year learning English prior to gaining entrance to Blackwood School, increasing the average age of both cohorts. Twenty-five percent of the students in both programmes were 18 years of age and ten percent of the IBD cohort were 19 years of age.

In terms of cultural composition, the two groups were similar. Around 60% of the students in the IBD programme were Caucasian, of the remaining 40%, 25% were of Asian background and spoke English as a second language. In contrast, around 50% of the students within the HSC programme were Caucasian and 50% were of Asian background. Of these Asian students, 50% of them speak English as a second language.

Given this background and context, the subsequent sections compare and evaluate the implemented and achieved curricula.

5.2 ISSUES RELATED TO THE DELIVERY OF THE IBD AND HSC PROGRAMMES

Teaching staff play a pivotal role in the successful delivery of a science programme. The perspectives of the three science teachers involved with delivering these two parallel science programmes were sought to address the second aim of the study:

Research Objective #2

To examine teachers' views about the issues involved in teaching, learning and assessment in the IBD and HSC programmes at the school.

The IBD teachers, Beryl and Christine, had both been teaching science at Blackwood School for many years. Beryl was an experienced HSC biology teacher, and Christine was an experienced HSC chemistry teacher. The HSC teacher, Heidi, joined the school more recently, but had previously taught on senior biology and chemistry programmes overseas. It should be noted that the teachers' personal world views could be reflected in their views of the two programmes.

To examine the teachers' views of the issues related to the delivery of the two programmes, each of the teachers were interviewed at various intervals during the two years of the study. During the interviews, the two IBD teachers were asked to draw on their previous experiences of teaching in the HSC science programmes to help make comparisons with their current involvement with the IBD programme.

Heidi, the new HSC teacher, was also consulted for her perspective on the HSC, drawing from her experience overseas. Observations of lessons were also conducted during each of the two years for each group of students. Further details of the data collection and analysis methods can be found in Chapter 3.

During the analysis of the teacher interview data, three major themes emerged. The first was related the depth of study required by the students in each of the programmes (discussed in Section 5.2.1), the second was related to time constraints and time management issues experienced in both curricula (discussed in Section 5.2.2) and the third was related to differences in the way in which the teachers managed the available resources (discussed in Section 5.2.3).

5.2.1 Depth of Knowledge: The Teacher Perspective

A repetitive theme that emerged during interviews with teachers was the academic level to which the students should be taught to prepare them for the external examination. The amount of knowledge required by the students was identified in terms of both the breadth (the range of topics within a subject area) and depth (the understanding required, often supported by the level of mathematics needed, within the subject area). A detailed comparison into the breadth and depth of the intended curricula is described in Chapter 4 (Section 4.2.3).

The difference in breadth and depth had several repercussions. According to the IBD teachers, to cope with the demands of teaching to the depth required by the IBD, both of the teachers felt that they experienced a heavier workload, involving additional research and preparation of materials for lessons, than their HSC counterpart. One of the IBD teachers, Christine, "found the challenge stimulating" after years of teaching the HSC chemistry programme.

In contrast, the HSC teacher, Heidi, observed that, in the HSC syllabi, the content lacked depth compared with her previous teaching experiences in senior science disciplines overseas. She also found the knowledge level required by the students was difficult to gauge when comparing the syllabus documents with past papers. Heidi felt that the examination papers for the HSC programme was becoming increasingly difficult as the HSC programme (launched in 2000) became more established. This concern was endorsed by the two IBD science teachers, Beryl and Christine. Heidi was of the opinion that the contextualisation of topics within the HSC course provided interest for both the students and for her. Examples of contextualisation in the HSC programme are referred to in detail in Chapter 4 (Section 4.3.1). One of the IBD teachers, Christine, felt that the contextualisation of the HSC chemistry course had considerably increased the breadth of the subject content. Although she agreed that this change provided interest and relevance to the chemistry course, she was of the opinion that the change was at the detriment to the depth of the course content.

Because the IBD programme required a greater depth of knowledge than the HSC programme, both of the IBD teachers felt that the previous training and level of qualification of a teacher could impact on their ability to successfully implement the IBD programme. One of the IBD teachers, Christine, felt that having a specialised BSc degree in chemistry had helped to prepare her for teaching the IBD chemistry programme. In her opinion, a general education degree, such as the BEd, with a science major, would not be as helpful. Some of the chemistry topics that were covered in the IBD syllabus, such as stoichiometry, had been introduced during Christine's university degree programme, indicating the depth required by some sections of the IBD syllabus. This issue of pre-qualifying experience was one that has also been raised in the U.S. (National Research Council, 2002; Mathews & Hill, 2005). A key recommendation emanating from these studies was that IBD teachers be qualified with a full science degree, before completing a teacher training qualification, to equip them with the essential subject knowledge.

The other IBD teacher, Beryl, had a general education degree. Beryl experienced difficulty in identifying the depth of knowledge required, particularly in the independent research area. To help her to update her knowledge and skills, she attended an IBO professional development conference in India mid-programme. She felt that the conference was useful in terms of sharing the expertise of more experienced IBD biology teachers and to help her to build a network of contacts.

Ongoing professional development is important from the point of view of a teacher's subject specialisation and to ensure its currency, particularly given the rapid rate of scientific progress. It is also important for teachers to be aware of current educational ideas and pedagogies in order that the students' learning experience is maximised. Both of these factors are likely to enhance student interest and achievement.

5.2.2 Time Constraints and Time Management

An issue for all three of the science teachers was that of time management. Although the respective programmes specified teaching times for syllabus content, all three of the teachers expressed difficulty in covering the substantial subject content in addition to the other activities required within their programme, such as assessments and laboratory work.

The school timetable allocated nine, 50-minute periods per two-week cycle for each senior subject. For the IBD programme this included one 50-minute period for independent study. One of the IBD teachers felt "overwhelmed by the shear content" of the chemistry course and decided to teach during the whole timetable allocation, encouraging independent study outside of classroom time. Beryl, on the other hand, encouraged independent learning during the stipulated timetable period, but expressed that some of her students were unsure of how to cope with this independence.

The HSC teacher, Heidi, also commented that the volume of content to be covered restricted her teaching. Heidi felt that although the contextualisation of the HSC made the programme more interesting, the heavy syllabus content meant that there was no time to pursue avenues of interest.

The in-depth examination of the content covered by the syllabus documents in Section 4.2.1 and the examination questions compared in section 4.4.2 supported that the IBD syllabus has more depth in terms of both the physics content and the mathematical application of physics principals required. Whereas the HSC syllabus has more breadth, in that the application of physics principles is embedded within a diverse historical and social context. The teaching staff all agreed strongly with these findings.

The IBD teachers also expressed the need to allow time for the internal assessments. Although the only section of the IBD science programme that is required to be assessed internally is the practical laboratory work, this is rigorously reported on a complex pro-forma, to ensure that all of the skills and activities are completed adequately. One of the IBD teachers found that by completing all of the requirements for the practical work assessment during the first year of the course, there was more time in the second year to complete the required content.

From the HSC perspective, Heidi commented that the time required for internal assessment for the HSC programme, which includes substantial practical and written assessment, detracted from class teaching time. She observed that this assessment format was not of educational benefit to the student, as the marks collected from the internal assessment process were required to be of a summative rather than formative nature to ensure that they did not disadvantage the students' final grade. (A low mark from a mid semester assessment could considerably reduce the student's final submitted school mark which, in turn, affects a student's placement in the final external examination results).

Some relief from these time constraints was found for the IBD students and their teachers in Term 4. During this term all Year 12 students at Blackwood School had study-leave and did not have to attend classes. As the IBD external examinations were held after the HSC examinations, the IBD coordinator obtained permission from the Principal for the students' class time to continue into Term 4. Thus, IBD teachers were able to extend their programmes by a week, which both teachers found invaluable. During this pre-examination time the HSC teacher, Heidi, held extra tutorials to assist her students.

All three teachers were concerned about the demands of the wider school curriculum and the impact that this had on their senior students. These demands included attaining positions as student officers (such as, prefects and sports and house captains) and participating in the many extra-curricular activities available, including, music, drama and sports. All of these activities exacerbated the already considerable time constraints of the students. According to each of the teachers, these extra curricular activities impinged on class time and affected teaching and learning targets.

Interviews with these teachers indicated, for both programmes, there were considerable pressures to cover the content and to include all of the internal assessments within the teaching hours available. Whilst each of the teachers found innovative ways to help to overcome and alleviate some of these pressures, they generally were concerned by the time constraints.

5.2.3 Management of Resources

Another theme that emerged during interviews with these teachers was related to differences in the amount and types of resources available to teachers in the IBD and HSC programmes. The high fee-paying school was generally well resourced, however issues emerged during the implementation of the IBD programme concerning the teaching and learning resources, allocated rooms and staffing. With respect to science resources, the school was generally well equipped; however, for different reasons, teachers on the two courses were concerned about resources.

For the IBD teachers, there were no specific text books available, reflecting a flexible approach to cater for the IBO's international spread of schools. Whilst this was a sound idea, it required Christine and Beryl to consult many sources, further increasing their workload. Both teachers claimed that researching relevant texts and websites was time consuming and unsatisfactory. Clearly this problem is one that has been experienced by other IBD teachers around the world as, since this study commenced, the IBO website has been further developed to provide a facility for sharing resources and to make possible the networking between IBD teachers. In response to teacher demand, a publisher has also been commissioned by the IBO to produce a definitive textbook.

All three of the teachers agreed that the resources available for the HSC programme were adequate. A combination of supportive text books and study guides, specific to the HSC programme, in addition to a website of past examination papers, notes and supportive documentation were available. These resources have been built up by HSC science teachers over the five years that the HSC syllabus had been running, and proved to be most useful to Heidi, the HSC teacher.

A further issue of concern to the teachers on the IBD science programme was the equipment allocated to the laboratories. The science laboratories provided by Blackwood School were well equipped for general senior science experiments and all three of the teachers agreed that they were adequate for the HSC programme. However, the IBD teachers did not feel that the equipment and resources were adequate for the more advanced IBD programme. Prior to the commencement of the programme, funds had been made available by the school, but the IBD teachers did not know what equipment would be required and were not confident to make such a large expenditure without experience in teaching the programme. This left the IBD programme with less adequate equipment in some areas. Both of the IBD teachers were adamant that, for the IBD programme to be successful, the laboratory equipment needed to be improved to allow opportunities to run the more advanced experiments required by the IBD syllabus. By the end of the programme the IBD teachers felt competent to invest in the relevant equipment using the budget provided in the coming year.

Interviews indicated that another issue, related to resources, was that of class size. The size of a class can impact on the classroom environment in terms of classroom management, comfort, teacher attention and the learning and teaching opportunities. Because of the low enrolment on the IBD programme, large class size was not an issue for these IBD teachers. The HSC science classes, however, were larger than previous years because the introduction of the IBD prevented an even distribution of students.

Heidi, the HSC teacher, complained that her relatively large class created a number of associated issues, including, coping with large groups during practical work, problems with observation space during demonstrations; and difficulties of providing individual help. To overcome these problems, Heidi combined her selected HSC study texts with an innovative scheme for study-buddies. Creating a study-buddy culture involved pairing the students for the purpose of discussing questions, homework, problems and general support over the two-year programme. The students quickly adopted the approach and Heidi felt that this made the management of the large class more reasonable. Observations of Heidi's classes over the two years of the study indicated positive classroom dynamics, with students that were both focused and motivated.

All three of the teachers raised the issue of opportunities for the local provision of external resources and professional development. In terms of resources, the IBD teachers found it difficult to obtain examination information and resources for guidance and formative assessment purposes. It is noted, however, that past examination papers are now available for purchase online, relieving this issue. The HSC programme teacher, Heidi, found that the local Science Teachers Association (STANSW) provided a range of resources and activities that are focused around the HSC requirements and networking opportunities for teachers. Unfortunately these resources and activities were not relevant to the IBD programme.

With respect to professional development opportunities, the two IBD teachers, Beryl and Christine, found online networking with other IBO schools helpful. They remarked that other teachers were willing to share resources and discuss problems with them. The IBO provided professional development to both teachers at its' Asia-Pacific Region annual conference in New Zealand prior to the start of the programme at Blackwood School. However, not all subject areas are covered each year, particularly the less popular physical sciences, so although Beryl was able to attend the India, which catered for biology teachers, Christine did not benefit. As more Sydney schools are beginning to offer the IBD, more local networks and opportunities for professional development are emerging, which will provide better support for the IBD science teachers.

For the HSC teacher, Heidi, one particularly useful STANSW event for professional development was 'Meet the Markers', during which BOS representatives and teachers who had been HSC examination markers shared their expertise to enable colleagues to guide their own student responses. Heidi found this a valuable opportunity.

Heidi's experience teaching overseas has brought some different insights to the study compared to the NSW experience of Christine and Beryl. Hence the world view of each of the teachers may have impacted on their responses to the two programmes.

Having examined teachers' views of teaching issues related to the two programmes, students' views were then sought. The next section examines students' views of the learning environment on both programmes.

5.3 STUDENTS' PERCEPTIONS OF THE LEARNING ENVIRONMENT

When examining or evaluating curricula, attention can tend to focus on examining the extent to which a curriculum achieves various aims and often neglects to examine the instructional process occurring in the classroom. Despite this, there is considerable argument to include aspects of the instructional process and learning environment dimensions as part of a curriculum evaluation (Fraser, 1981; Fraser & Teh, 1994; Maor & Fraser, 1996; Walberg, 1975). The present study used both quantitative and qualitative research methods to compare the experiences perceived by students during the implementation of both science programmes to address the third research objective:

Research Objective #3

To investigate whether differences exist for students enrolled in IBD and HSC programmes in terms of their views of the learning environment.

Practical work is considered to be of paramount importance during the teaching and learning of science (Black, 1995; Fensham, 1992; International Baccalaureate Organisation, 2001). Practical work can be used to reinforce subject knowledge and to provide opportunities for a more hands-on approach to the learning of scientific skills and processes as well as providing opportunities for group work. Because the laboratory components of the IBD and HSC science were considered to be important aspects of both programmes, the Science Laboratory Learning Environment (SLEI: Fraser, Giddings & McRobbie, 1995) was selected to examine students' perceptions of the learning environment created in this situation. Data collected using the SLEI was used to provide an overview of the learning environment for the two programmes that would act as a springboard from which qualitative data could be collected.

This survey approach involved the pooled judgements of all of the students in each group, based on their experiences over a period of time. The SLEI has a total of 35 items with seven items in each of five dimensions that were considered to be important to the science laboratory learning environment, namely, Student Cohesiveness (the extent to which students know, help and are supportive of each other); Open-Endedness (the extent to which the laboratory activities emphasise an open-ended divergent approach to experimentation); Integration (the extent to which the laboratory activities are integrated with non-laboratory and theory classes); Rule Clarity (the extent to which behaviour in the laboratory is guided by formal rules); and Material Environment (the extent to which the laboratory equipment and materials are adequate). The SLEI has been used and validated extensively in Australia, making it a good choice for use in the present study. For more information related to these dimensions and the aspects that they assess see Section 2.5.3.

A review of past literature indicated that the environment of the science classroom can influence the teaching and learning experience of the students and teachers (Fraser, Giddings & McRobbie, 1995). To provide students with a suitable senior science experience, classes should be held in a laboratory rather than in a general classroom. At Blackwood School, senior classes (Years 11 and 12) were given priority in the distribution of teaching areas during school timetabling. As a result, all senior science classes were timetabled to be held in laboratories, potentially providing an ideal situation.

For each scale, the average item mean (the scale score divided by the number of items in the scale) was calculated separately for students enrolled in the IBD and HSC programmes. Figure 5.1 depicts the average item mean for each scale of the SLEI. The scores indicate that the perceptions of students' enrolled in the IBD course are more favourable for all SLEI scales than for their counterparts enrolled in the HSC programme.

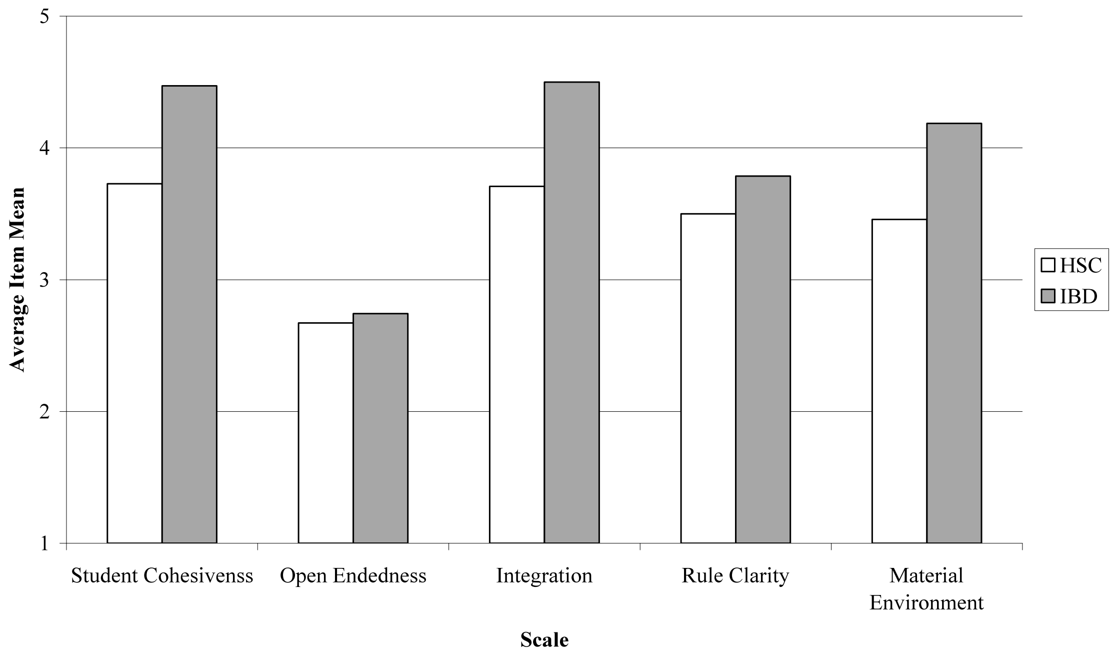


Figure 5.1: Difference between IBD and HSC Scores for Students Perceptions of the Actual Science Laboratory Environment (*N*=11 IBD responses and 19 HSC responses)

To examine the magnitudes of these differences (as recommended by Thompson, 1998, 2001), as well as their statistical significance, effect sizes were calculated in terms of the differences in means divided by the pooled standard deviation. Table 5.2 reports the average item mean (the mean divided by the number of items in a scale), standard deviation and difference for each SLEI scale.

Statistically significant differences were found for three of the five learning environment scales, namely, Student Cohesiveness, Integration and Material Environment. The effect sizes, for those scales with statistically significant differences, range between over half of a standard deviation (0.59) and over three quarters of a standard deviation (0.82).

Table 5.2: Average Item Mean, Average Item Standard Deviation and Difference (Effect Size and *T* Test Results) between Scores for Each SLEI Scale for Students Enrolled in IBD and HSC Science Classes

Scale	Average Item Mean		Average Item Standard Deviation		Difference	
	HSC	IBD	HSC	IBD	Effect Size	*t*
Student Cohesiveness	3.72	4.47	0.41	0.50	0.82	4.41**
Open-Endedness	2.68	2.74	0.57	0.54	0.05	0.03
Integration	3.71	4.49	0.79	0.49	0.61	2.99**
Rule Clarity	3.50	3.79	0.57	0.44	0.29	1.47
Material Environment	3.45	4.18	0.63	0.60	0.59	3.12**

**$p<0.01$

N=11 IBD students and 19 HSC students

These results suggest educationally important differences between the perceptions of the science laboratory learning environment for students enrolled in IBD and HSC programmes. To examine the reasons for these differences, qualitative data collected during interviews with the teachers and focus group interviews, were used.

5.3.1 Student Cohesiveness

The student cohesiveness scale assessed the extent to which students know, help and support each other. According to Table 5.2 students enrolled in the IBD programme perceived statistically significantly ($p<0.01$) more student cohesiveness than their counterparts enrolled in the HSC and programme.

A comparison of the social dynamics of the two groups (IBD and HSC) proved interesting. The same school spirit and ethos underpinned the wider curriculum for both groups, however, students enrolled in the IBD programme were exposed to a more holistic programme, involving the integration of subjects. The IBD students spent a considerable amount of time together during which they carry out a variety of activities. In contrast, students enrolled in the HSC programme, studied within an unconnected group of subjects that did not have a framework (see Section 4.1). Although students may have selected similar subjects to school friends, or meet up with friends during extra-curricula activities, this was not integral to the HSC programme.

Qualitative data, collected during interviews with the teachers and students of these IBD and HSC classes helped to provide insights into the difference in Student Cohesiveness scores. Firstly, the differences in class-size could help to account for this difference in scores, with the smaller IBD classes allowing for more student interaction. The IBD students were together for almost all of their subjects, had their study periods at the same time as their classmates and could generally be found together at lunchtimes. In addition, these students had, by their own admission, been treated as a special group within the school since the start of the programme.

In contrast, the HSC students whom were interviewed all had different timetables and different study periods throughout the week. It would appear that, although the HSC students were exposed to a ‘study-buddy’ system (see Section 5.2.3) to encourage a more cohesive climate of learning, the heavily content-based syllabus allowed only limited amounts of lesson time for students to work on problems with their ‘buddies’. The HSC students whom were interviewed admitted that they did not often work on problems together outside of the classroom as they did not have opportunities to meet with their peers.

5.3.2 Integration

The integration scale assessed the extent to which the laboratory activities are integrated with non-laboratory and theory classes. According to Table 5.2 students enrolled in the IBD programme perceived statistically significantly ($p<0.01$) more integration than their counterparts enrolled in the HSC programme. During focus group sessions, students enrolled in the IBD programme indicated that there was a strong link between theory lessons and laboratory work. However, some of the students found this distracting rather than helpful, as they would have preferred to concentrate on the theory without the interruption of practical sessions. One student described the move from theory into experiment as “… a hassle, getting all the equipment out for just a little practical, and then having to clear it all away again”. Other students, who were involved in the focus group interviews, were of the opinion that they learnt more by doing group work than individual experiments, although a minority felt that they were ‘copying’ the top students rather than sharing ideas. According to the IBD teachers, the smaller class sizes made it easier for them to organise shorter practical sessions for the students, and enabled them to provide opportunities for students to work individually.

The HSC students whom were interviewed, generally agreed that there was integration between the theory and practical work, although there was a range of views, reflecting the high average standard deviation (σ=0.79). It was expected that HSC students would experience a high amount of integration as the BOS advised that this should take place and carefully set out prescribed activities that link each theory point to practical activities. It is of interested that, in contrast to their IBD counterparts, the HSC students expressed a preference for more integration.

Interviews with the IBD and HSC teachers indicated that they felt that the disparity between the perceptions of the students in the two groups could be due to the high syllabus content demands of the HSC and the large HSC group size. The HSC teacher, Heidi observed that, to organise laboratory sessions for this large group, more management of equipment, time and space was required and that experiments took longer to set up and clear away. In addition, she felt that the larger sized groups made it more difficult to give assistance and left less opportunity for constructive laboratory work.

5.3.3 Material Environment

The Material Environment scale assessed the extent to which the laboratory equipment and materials are adequate. Students enrolled in the IBD programme perceived statistically significantly (p<0.01) more Material Environment than their HSC counterparts. It would appear from interviews with students that these differences are due largely to the allocation of rooms to the two groups.

The laboratories available to both the IBD and HSC students were equally well equipped, with the availability of science equipment being identical. In both cases the laboratories were used largely by each teacher as a base room (a room where one teacher taught the majority of their science classes throughout the week). However, the classroom in which the HSC group carried out the largest portion of their learning was in the older and somewhat darker part of the school. Despite Heidi's attempts to improve the ambiance of the laboratory by displaying students' work, posters, plants and a tank of fish, it was considered, by the HSC students whom were interviewed, to be inferior to the newer, brighter laboratories in which for the IBD students carried out their learning. Focus group interviews revealed that many of the HSC students were of the opinion that their IBD counterparts were favoured by the school. Many of these students complained that the IBD students were more privileged and that, as a result, students enrolled in the HSC programme were "missing out". The HSC students involved in the focus group interviews were concerned that the IBD students were provided with more resources.

It is evident from analysing the results from the SLEI that the IBD students were more positive about every aspect of their implemented curriculum compared to the HSC students. The structure of the IBD programme encouraged a high level of cohesiveness, especially as the current cohort is so small and that the students spend a considerable amount of time together. The HSC programme, however, did not engender cohesiveness due to its diversity of subjects and relatively large number of students to be accommodated. This group size in turn affected the inclusion and organisation of practical work, and allocation of laboratory space and equipment. The benefits of being part of a small group had positive influences on the IBD students' view of their practical work and material environment, whereas, the HSC students felt disadvantaged in these areas.

Having studied the implemented curriculum, the following section investigates aspects of the achieved curriculum. This will help to ascertain the relative success of the two programmes using a variety of parameters.

5.4 COMPARING STUDENTS OUTCOMES

To examine the achieved curriculum, student outcomes can be measured in a variety of ways. For the purposes of this study, outcomes include whether or not students' chose to follow a science-related career path; students' enjoyment of their senior school science experience; and their final examination scores. To this end, this section addresses the fourth research question:

Research Objective #4

To examine whether the outcomes of students enrolled in the IBD and HSC science programmes differ in terms of:

a) their propensity and desire to pursue a career in science;
b) whether the science programme lived up to their expectations; and
c) achievement according to the University Admissions Index.

This section addresses this research aim in four sections. Section 5.4.1 reports the findings related to students' propensity for science-related careers, Section 5.4.2 provides information about the students' desires to pursue a science-related career, Section 5.4.3 reports students' satisfaction with their chosen programme and Section 5.4.4 examines students' scores for the final examination and University Admissions Index (UAI).

5.4.1 Propensity to Pursue a Science Career

It is becoming increasingly difficult to attract girls into science related careers (Fullerton & Ainley, 2000; Schreiner & Sjøberg, 2007). It was considered important, therefore, that the science programmes offered at Blackwood School have the potential to attract students to study science. To study a science subject is compulsory within the IBD programme, but not within the HSC programme. To examine whether differences exist between the extent to which the IBD and HSC attracted students with intelligence areas that were more suited to the study of science, and hence encourage them to pursue a science career, the Multiple Intelligences Checklist for Adults and Senior Secondary students (MICA: McGrath & Noble, 2005) was administered.

The Multiple Intelligences Checklist for Adults and Senior Secondary Students (MICA; McGrath & Noble, 2005) is a self-assessment of students' perceived strengths and weaknesses, based on Gardner's (1993) theory of Multiple

Intelligences. Although the MICA was developed largely as a teaching and learning tool, past studies have indicated that the intelligence areas in which students demonstrate a strength can provide an indication of the type of career that the student might be suited (Kallenbach & Viens, 2002). It was anticipated that there may be differences in student's perceptions of their strengths, depending on which senior programme had attracted them.

Gardner (1993) identified eight key areas of intelligence, three of which were identified by McGrath and Noble (2005), as areas that may naturally lead students to choose and perform well within a science-related career, namely, Logical/Mathematical, Naturalist, and Spatial/visual. (Section 2.6 provides a description of the types of skills likely to be displayed in each of these key areas.) With this in mind, students' responses to the MICA were analysed to provide an indication of the extent to which students' selection of science courses (IBD and HSC) might have been influenced by a perceived strength in these three intelligence areas.

The MICA consists of 56 items, with seven items related to each of the eight key areas. Students were required to rate their ability in these areas by indicating whether they perceived each statement to be very true (scoring a 3), somewhat true (scoring a 2) or not true (scoring a 1) for them. The score was then tallied accordingly. Analysis of the data involved identifying, for each student, the two key areas that were awarded the highest scores (considered to be strengths) and the two key areas that were awarded the lowest scores (considered to be weaknesses). See Chapter 2 for further details related to the development and modification of the MICA and Chapter 3 for details related to the use of the MICA in the present study.

This section reports the results in terms of an overview of students' perceived areas of strength and weakness, followed by a closer examination of students' perceptions of the three intelligence areas that were considered to be related to science, these being, Logical/Mathematical, Naturalist, and Spatial/Visual.

Areas of Strength and Weakness

Figure 5.2 provides a graphic representation of the percentage of students in the IBD and HSC programmes who considered each of the eight areas of intelligence to be strengths. The results indicated that students who enrolled in the IBD programme felt that they had strength in five of the eight areas of intelligence, the exceptions being Naturalist, Body and Space/vision. In contrast, students enrolled in the HSC programme perceived themselves as having strengths in all but one of the eight areas of intelligence, the exception being Naturalist.

Figure 5.3 provides a graphic representation of the percentage of students who scored lowest for each area, indicating an area of perceived weakness. The results indicated that, for students enrolled in the HSC programme, five areas of intelligence were considered to be areas of weakness, namely, Word Intelligence, Music Intelligence, Naturalist Intelligence, Space and Vision Intelligence and People Intelligence. For students enrolled in the IBD programme, six of the eight areas of intelligences were perceived to be areas of weakness, the exceptions being Space and Vision Intelligence and People Intelligence.

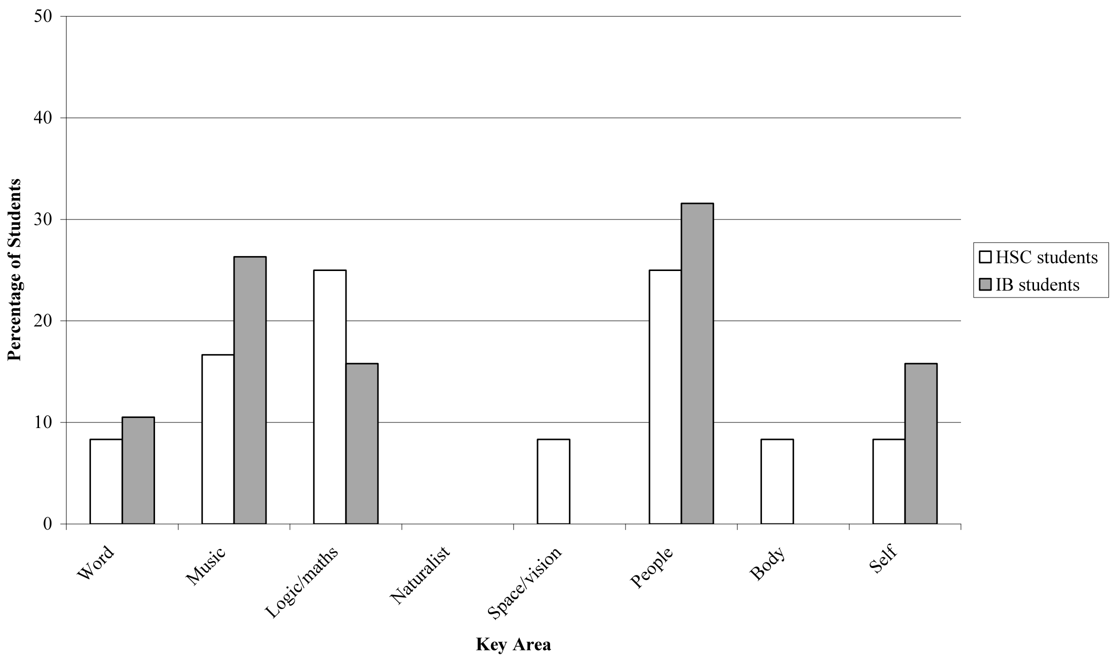


Figure 5.2: Percentage of IBD and HSC Students that Scored Highest for each Area of Intelligence (*N*=19 IBD responses and 24 HSC responses)

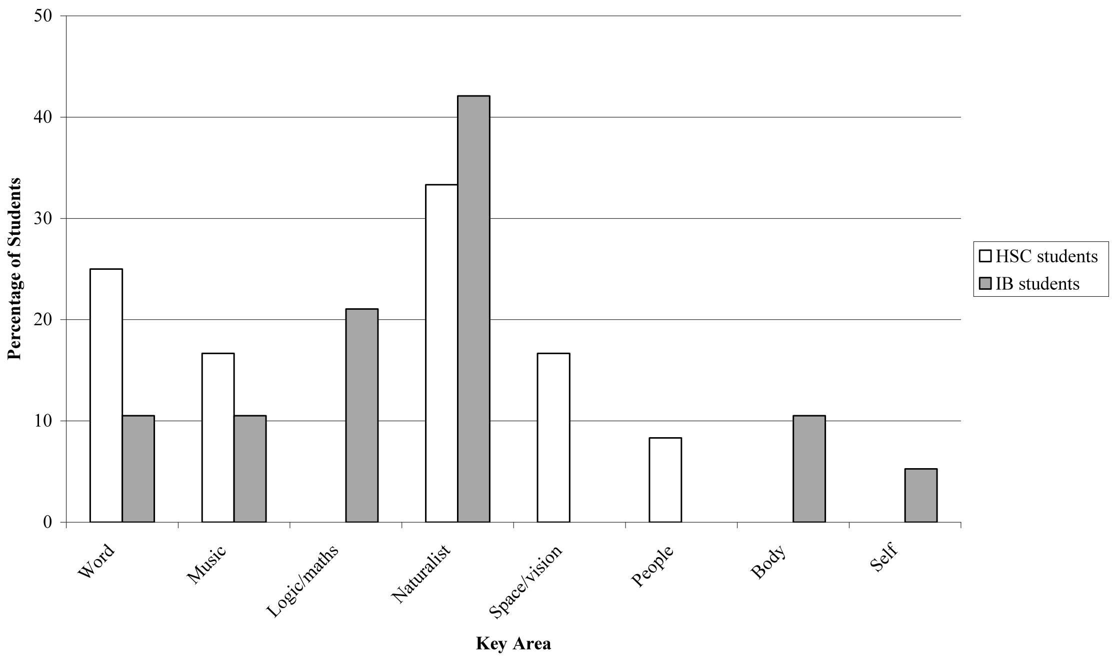


Figure 5.3: Percentage of IBD and HSC Students that Scored Lowest for each Area of Intelligence. (*N*= 24 HSC responses and 19 IBD responses)

These results would suggest that few of the students felt that they had particular strengths in the areas of intelligence considered to be more science related. This is despite IBD students having chosen a programme with a compulsory science subject and HSC students having chosen to study at least one science subject although at the start of the study. An attempt to explain these anomalies is presented in the next three sections.

Logic and Mathematics Intelligence

The Logic and Mathematics Intelligence area examined students' belief about their ability in detecting patterns, scientific reasoning and deduction, hypothesizing, experimenting and whether they felt that they could analyse problems and perform mathematical calculations. This category included such statements as: "I can 'see' a situation more readily if I can measure, count, categorise or analyse the material" (McGrath & Noble, 2005).

The self-assessment of students enrolled in both the IBD and HSC programmes indicated that for the Logic and Mathematics Intelligence with over 20% of the IBD students considered this area to be one of their weakest and none of the students enrolled in the HSC programme perceived Logic and Mathematic Intelligence an area of weakness. Mathematics is a compulsory subject within the IBD and, as found with the physics content, a demanding and rigorous course. The IBD students at Blackwood School were of mixed academic ability and many of them were finding the course challenging. Focus group interviews indicated that this level of difficulty could explain why IBD students perceived Logic and Mathematics Intelligence to be an area of weakness.

The level of confidence that the HSC students had in mathematics was considered surprising to the teachers as several HSC students were studying for the lower level of mathematics. The teachers did not consider this level to be adequate preparation to support a senior science course but it would appear, from this data, these students were feeling confident and coping within this level of mathematics. The results of the focus group interviews indicated that this area of intelligence might be influenced by the level of mathematics that students were studying and, as such, may not indicate a tendency towards a science-related career.

Naturalist Intelligence

The area of Naturalist Intelligence examined a students' belief in their ability to notice the characteristics of natural things and to categorise them. This area includes caring for animal or plants and involved observation skills. Statements in this category included "I can recognise and name many trees and plants", and "Animals usually respond well to me because I have a natural affinity with them and care about them" (McGrath & Noble, 2005).

Surprisingly, none of the students enrolled in either the IBD or HSC programmes perceived Naturalist Intelligence as an area of strength, and a high percentage of students enrolled in both the IBD and HSC programmes (33% and 42%, respectively) indicated this was an area of weakness. Discussions with students indicated that they did not identify with the scenarios presented in the MICA; several of which involved bush-care and gardening. Even those students studying biology claimed that it was human biology that they found interesting, and little of either syllabus covered significant plant biology. For this cohort of science students it would appear that Naturalist Intelligence is not a good indication of whether a student had a propensity for a science-related career.

Space and Vision Intelligence

The Space and Vision Intelligence area examined a student's belief in their ability to interpret and create visual images and diagrams, and to understand the relationship between images and meanings. Statements in this category could also be seen to relate to scientific skill strengths, for example, "I can successfully read maps…" can be related to the analysis of diagrams and "I often notice visual details is an important skill in scientific observation and recording …" (McGrath & Noble, 2005).

Of the students enrolled in the HSC programme 8% perceived the Space and Vision intelligence as an area of strength and 16% perceived that it was an area of weakness. In contrast, students enrolled in the IBD programme did not perceive this area of intelligence as either a strength or a weakness.

The profiles presented in Figures 5.2 and 5.3 suggest that students did not have a propensity for science related careers, reflecting international trends in which western teenagers, particularly girls, were disengaged with science (Curtis, 2002; Schreiner & Sjøberg, 2007). However, interviews with students indicated that the statements on the MICA may be influenced by factors, other than a student's intelligence area, such as general interest or level of mathematics that they are currently studying. Although not part of this thesis, the students enrolled in both programmes were fascinated by the insights provided by the MICA into their personal intelligences and felt that this new understanding would influence their approach to studying.

5.4.2 Desire to Pursue a Career in Science

Whilst the MICA was administered to provide an indication of the propensity of students for learning science, students were also asked to provide an indication of whether they would choose a science-related career path. To provide an indication of whether changes had taken place during the course of the programme students were asked the same question at the beginning and at the end of the two years.

At the beginning of the two-year programme, 38% of the IBD students indicated that they intended to choose science-related careers compared to 53% of HSC students. This was not considered surprising as all of the HSC students had chosen to study a science subject whereas science was a compulsory subject in the IBD programme. When students responded to the same question at the end of the two year programme, however, their responses indicated that 60% of the IBD students (compared with 38% initially) and 33% of the HSC students (compared with 53% initially) intended to choose a science-related career.

Although the MICA results did not report promising prospects for either of the programmes to produce scientists, student responses to the question about their career plans was more positive. Similarly, the MICA responses of the HSC students were not promising, although stronger than those of the IBD students. Focus group interviews indicated, however, that student decisions not to pursue a science career may be influenced by a lack of information about the range of science-related careers available. Some of the students discussed a desire to work with people rather than in a laboratory, providing an insight into their perceptions of a scientist and what a science-related career might entail. These results were supported by past research that has indicated that science careers are often perceived as unattractive (Lavonen et al, 2008; Schreiner & Sjøberg, 2007).

5.4.3 Student Satisfaction with their Selected Programme

During the last three weeks of the IBD and HSC programmes, a questionnaire (including both open and closed responses) was administered to students enrolled in both programmes to provide an overview of students' satisfaction with their choice of programme. Students were required to respond to the closed questions on a four-point rating scale ranging from Strongly Disagree (scored 1) to Strongly Agree (scored 4), with an additional option to respond No Opinion. To help to explain reasons behind students' responses to the questionnaire and to provide deeper insights, focus group interviews were conducted.

This section reports the findings for four aspects of student satisfaction. First, whether students enjoyed the programme, second, if they were dissatisfied with their selected programme, third whether they felt they had achieved to their full potential and finally, whether they felt that they should have selected the alternative programme.

The results of the survey, for all four questions, indicated that, whilst the trends for each were similar, the HSC students had slightly more favourable views of their programme than their IBD counterparts. Focus group interviews with students were used to help to explain students' responses to each of the questions. Figure 5.4 illustrates the mean score for the students' responses to the survey.

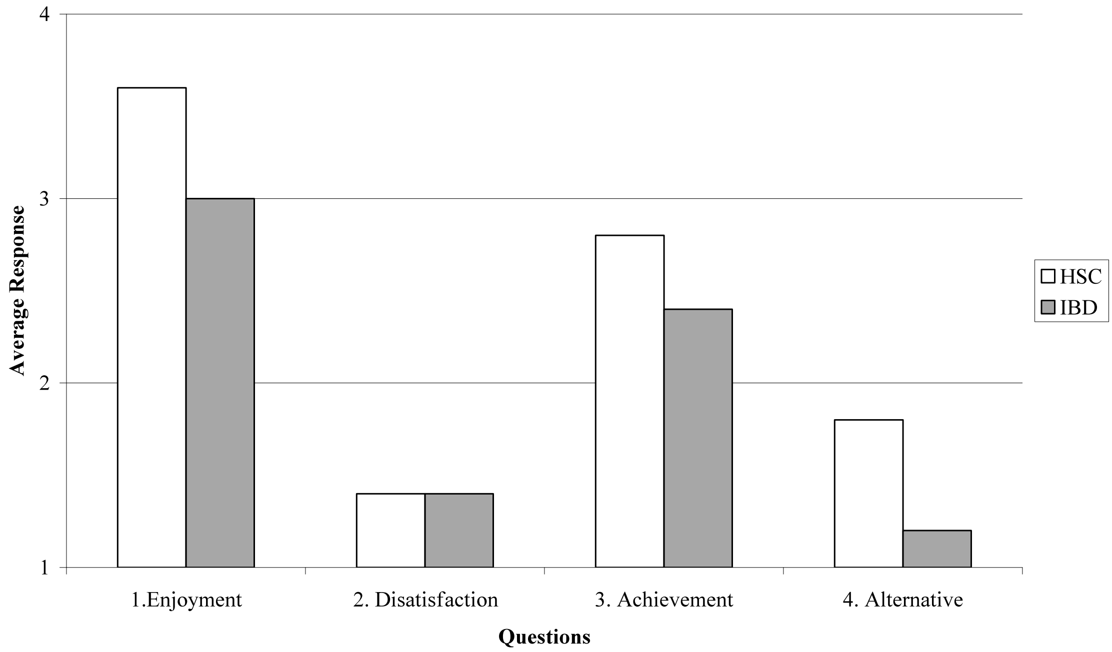


Figure 5.4: Average Response to Questions Related to Students' Experiences of their Selected Programme (*N*=11 IBD responses and 18 HSC responses).

Enjoyment of the Programme

The aim of the first question was developed to gauge the degree to which students' enjoyed each of the programmes. As depicted in Figure 5.4, responses from HSC students were slightly more favourable than those from IBD students. 78% of students enrolled in the HSC programme and 54% of the students enrolled in the IBD indicated that they enjoyed their programme of study. Focus group interviews with students indicated that students in both programmes had mixed views about how much they enjoyed their selected programme.

Students enrolled in the IBD programme were keen to discuss the science topics that they had enjoyed, and two of the students referred to the laboratory sessions as being a highlight of the science programme. To this end, one of the IBD students commented that “The labs were good fun … I wish we’d done more”. It was interesting that two of the IBD students, both of whom were studying both sciences – chemistry and biology – expressed that they would have preferred more practical work. One IBD student said, “I really enjoyed it, there was so much to learn [it was taught in] so much more depth than the HSC programme”. Another student had enrolled in the IBD science programme because drama was not available in the HSC programme and, despite her lack of choice, she expressed that she had enjoyed the programme.

It was interesting to note that students studying both chemistry and biology seemed, in some respects to enjoy the programme more, regardless of whether they were enrolled in the HSC or the IBD programme. Interviews indicated that these students felt that the overlap of skills and concepts in the two sciences was beneficial to their understanding of each subject.

Although generally satisfied with their programme, as indicated in the profile, the HSC students were less inclined to discuss the types of activities that they felt had added to their enjoyment of their science courses. However, in response to the open question “I most enjoyed…” one of the HSC students commented that “Study-buddy groups were really useful”. This activity, introduced to assist the teacher with classroom organisation and to help students, was also described as beneficial by four other HSC students during focus group interviews.

Dissatisfaction with the Programme

The second question was asked to determine whether students wished that they had selected the alternative programme. Most students disagreed with this statement but a small group of students (enrolled in both the IBD and HSC) expressed dissatisfaction with their chosen programme of study (see Figure 5.4). The focus group interviews indicated that their reasons for the dissatisfaction with the choice of programme differed for the two groups.

The HSC students whom were interviewed, were dissatisfied with the variety of subjects offered and with their achievement. Some of the HSC students indicated that they were disappointed that the HSC science subjects offered less depth than the IBD science subjects. These HSC students went on to explain that, on occasions when they had compared notes and homework requirements with friends, they had felt that, compared with the levels of knowledge and understanding required by the IBD, their programme was inadequate.

Throughout the two years of the programme, it was voiced that the IBD students were considered to be an elite group within the school (brought up during many of the interviews and experienced by the researcher throughout the study). These opinions were echoed, in terms of rivalry and sometimes jealousy by the HSC students who expressed dissatisfaction. These students articulated their views on the apparent preferential treatment of the IBD programme within the school.

Those IBD students who expressed dissatisfaction with their selected programme during the focus group interviews indicated this was related to their concern for their relative academic performance. These students felt that they could have achieved better results on the less rigorous HSC programme. During focus group interviews some of the IBD students expressed a regret at not having the choice to study physics (omitted from the programme due to low enrolments) and again, these students felt that they might have achieved better results had they enrolled in the HSC programme.

Achieved to their Full Potential

The third question asks students whether they felt that they had achieved their potential on their selected programme. The results depicted in Figure 5.4 indicate that the HSC students were slightly more positive in their response than their IBD counterparts, with 67% of the HSC students feeling that they had met their potential, and more than half of the students agreeing strongly. The students enrolled in the IBD programme appeared less confident than their HSC counterparts, with 60% of students agreeing that they had reached their potential, none of which were in strong agreement. Focus group interviews indicated that this difference in confidence was largely because HSC students had already received their final internal assessment grades at the time that the questionnaire was administered and that the IBD students had no indication of their relative success.

Focus group interviews with IBD students indicated that some of the students were positive about having reached their potential. One student observed “It [the IBD science programme] was very hard work – I hope I have done well”, and another stated “I feel that I’ve achieved more than I would have done on the HSC, the TOK [Theory of Knowledge core course] was good background – it felt like real study”.

It would appear that one IBD student, who also reported that she was dissatisfied with her choice in the programme, may have been more suited to the HSC programme. When asked why she did not feel that she had met her potential the IBD student looked quite tearful and commented that “It was all too hard…we should have been told”. Past studies have indicated that some schools require students to meet certain standards before they can enter the IBD programme. This was not the case at Blackwood School but careful monitoring may need to be involved to ensure that students are suited to the programme before they enrol.

Students enrolled on the HSC programme also made positive comments and indicated that they had met their potential. One student commented “This level was right for me and I’ve done well [on internal assessments]. The IB might have been too hard”. Another observed “I’ve worked really hard on my subjects and got good marks”.

Students in both programmes found the work load onerous and, towards the end of the programme, the IBD students appeared to lack the confidence of the HSC students with respect to their anticipated achievement in their final grades. The interviews indicated that the high percentage of weighting on the external assessment for the IBD, compared with the higher weighting for the internal assessment in the HSC, may have been a contributing factor.

Alternative Programme

The fourth question asked students whether they would have done better if they had chosen the alternative programme. On the whole, students enrolled in both the IBD and HSC disagreed with this statement. The results, reported in Figure 5.4, indicated that 80% of students disagreed with this statement. Of this 80%, almost half of the HSC students and 75% of the IBD students indicated that they felt very strongly that they had chosen the right programme. Of the remaining students, 15% of students had no opinion in this matter, leaving 5% of students who were dissatisfied with their choice of programme.

When the question of choosing the alternative programme was raised during focus group interviews, the majority of students from both programmes responded quite vociferously against the concept. Students enrolled in both programmes were generally pleased to have selected their respective programmes for quite different reasons. IBD students felt that their programme offered depth of knowledge. To this end, one student commented “This course was really much more intellectual – I feel really ready for university now”. HSC students, on the other hand were more likely to focus on the negative aspects related to the IBD. For example one HSC student commented “I’m glad I wasn’t a guinea-pig, it was nice being part of the main group”. Another stated “I’m glad I focused on my main subjects and didn’t have to do all that other stuff”. Some HSC students also felt that their programme was more flexible because, although they were able to start with up to seven subjects, they could drop one or two subjects if the workload was found to be too heavy.

Of all the students who were interviewed, two HSC students and one IBD student, reported that they felt that they had not met their potential and that they would have been more successful had they enrolled in the other programme. Discussions with their respective teachers indicated that the students enrolled in the HSC programme did not feel sufficiently challenged and would probably have benefited from being enrolled in the IBD programme. The IBD student, discussed in the previous section, had been overwhelmed by the academic rigour required and also would have benefited from being enrolled in the HSC programme.

While this section reported students' satisfaction of their selected programme the next section examines students' views of what their programmes had to offer.

5.4.4 Students' Views of their Respective Programmes

This section reports students' views of their respective programmes in terms of what they had to offer and is discussed in four parts. The first examines whether the students were satisfied with the range of subjects that the programme offered, the second investigates whether students were satisfied with the depth to which the course was covered, the third provides information about whether students felt that their selected programme offered better university opportunities and the fourth examines whether they felt that their selected programme provided better career opportunities. As with the previous sections, questions included both open and closed responses and the questionnaire was administered to all of the students towards the end of their programmes.

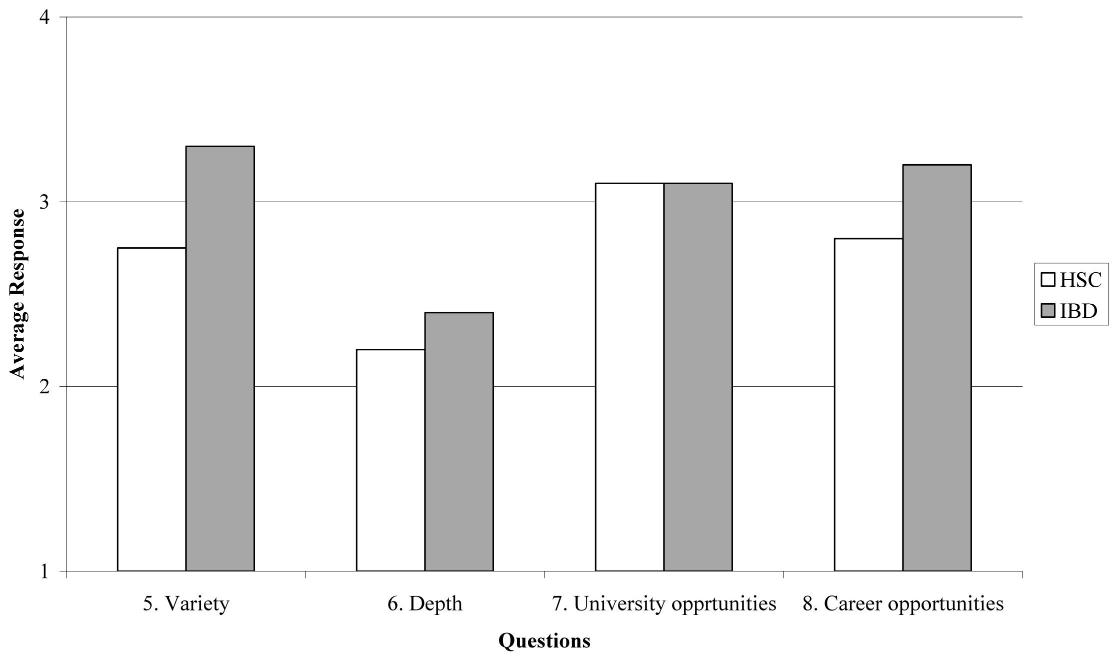


Figure 5.5: Average Response to Questions Related to Students' Views of their Selected Program (N=11 IBD responses and 18 HSC responses).

The mean score for students' responses to each of the questions is represented in Figure 5.5. The results indicated that, for students enrolled in both the IBD and HSC programmes, the trends were similar. In all cases the IBD students responded to each question slightly more favourably than their HSC counterparts. This section reports the results of the focus group interviews to help to explain students' responses to each of these questions.

Variety of Subjects

Responses to the first question indicated that students enrolled in the IBD programme were slightly more positive about the variety of subjects than those enrolled in the HSC programme (see Figure 5.5). However, almost 50% of the IBD students strongly agreed that their programme offered more of a variety of subjects, whilst the responses for the HSC students were more polarised with 30% strongly disagreeing that their programme offered more variety. Given that the HSC programme was able to include physics but not the less academic general science subject 'senior science' and the IBD programme did not include physics, the results were considered anomalous. During the focus group interviews, however, it became apparent that two IBD students who disagreed strongly to this question still wished that they had been offered the opportunity to study physics.

Focus group interviews also indicated that two HSC students had wanted to study a slightly less rigorous course for lower ability students, called 'HSC senior science'. Like the IBD physics course, low enrolment numbers meant that this course had to be cancelled. One student commented "I could have done better on [HSC] senior science because a lot of the [HSC] biology was too hard". It transpired that timetabling restrictions had also limited some choices and to this end, one of the HSC students commented: "I wasn't allowed to study three sciences, it wasn't fair".

Depth of Subjects

The results reported in Figure 5.5 indicated that students enrolled on both programmes were not convinced that their programme provided more depth in the subjects than the other programme. Closer examination of the results indicate that around 60% of the IBD students and 50% of the HSC students were of the view that their chosen programme had more depth however, 30% of the HSC students had no opinion on this matter.

It became apparent during the focus group interviews that both IBD and HSC students equated academic depth and rigour with workload. To this end, one stated "[The IBD programme] has been very hard work – we've worked much harder than the HSCs with all their free periods". One IBD student claimed to have regularly compared notes with an HSC student and she commented "All of our work has been much harder, right from the start". It would appear that these IBD students felt that the IBD science courses were more difficult than those offered in the HSC programme. Despite the perceived difficulty and concern related to the quantity of work that had to be memorised, these students felt that the IBD programme enjoyed status and involved doing, as one student commented "real study".

Like the IBD students, the HSC students whom were interviewed were concerned with the amount of theory that was required to be learned for the final examination. To this end, one student commented "I'm worried about finishing [the syllabus] in time" indicating that regardless of the depth or breadth of the study programme students still were anxious about facets of their current situation as examinations approach.

Some of the HSC students whom were interviewed were of the opinion that they had chosen the less rigorous option but, as one HSC student commented, they did not necessarily "… feel this was a bad thing". The interviews with the HSC students indicated that they were aware of the compulsory timetable of the students enrolled in the IBD programme and appreciated the comparatively lighter load. In some cases, students equated the depth of study and rigor with the amount mathematics content required. One student commented "Our [HSC] course did not include too much maths, not like the IBDs'…I couldn't have coped". The students that were enrolled in high-level mathematics units in the HSC programme disagreed with these comments. It was clear that the majority of the HSC students involved in the focus group interviews were feeling the pressure of their studies.

University Opportunities

Students were asked whether they felt that their chosen program offered potential in terms of opportunities for a university place. When the questionnaire was administered, the students were only weeks away from leaving school, so it was pertinent. The results shown in Figure 5.5 indicate that the majority of students on both programmes felt confident that their programme had equipped them for entrance in a tertiary education.

Of the students on the IBD programme, 90% felt that, having studied within this programme, they had better university opportunities than their HSC counterparts. Students enrolled in the HSC programme were more divided in their views (see Figure 5.5) with 66% agreeing that they had better opportunities of attaining a university place and half of these students agreeing strongly. However, nearly 20% of the HSC students disagreed with this view.

Focus group interviews revealed that HSC students developed a more positive outlook on the value of their programme towards the end of their two year programme. Sessions run by various New South Wales universities and the careers information service had clearly influenced their views of the value of the HSC. The HSC was the programme to which reference was made to, especially in terms of the HSC scores that were required for various courses. This information enabled the students to relate their own studies to possible courses.

During the interviews, students observed that the university application process was complex and the selection of courses was made more difficult because they were identified by unfamiliar titles. For example, a search on “science” at the University of Sydney produced 31 pages of information, and ‘bioinformatics’ was listed as a key area. This type of information meant little to the school students who were studying biology. One HSC student summed it up by saying “I thought it was so complicated when we were given the information. But now, if I like the sound of a course, and I have the right subject, I just have to get the right UAI [University Entry score].”

In contrast, IBD students lacked confidence in the tertiary admissions procedure. There was little information that related to either the IBD programme or the achievement requirements as they applied to them. To this end, one student commented “I hope they understand how much harder this course has been!” whilst another stated “When you ring up they [university faculty administrators] don’t know what the IB[D] is". Another IBD student added anxiously "I've heard that its worth a lot more – I hope that's right!"

Career Opportunities

The last question asked students whether they felt that their chosen program would give them better career opportunities than the alternative programme. The results indicated that students in both programmes felt that their programme would offer better career opportunities with IBD students responding more positively than HSC students (see Figure 5.5). 80% of IBD students compared to 67% of the HSC students agreed that there programme would offer better career opportunities.

During focus group interviews with both groups it became clear that, when responding to this question, students were generally considering the degree programme that they would enrol in rather than the long-term career prospect. The interviews indicated that three key factors had influenced students' choice of career, these being, television fiction series (particularly those with glamorous, successful female lawyers or doctors), a desire to be wealthy and to travel overseas. Amongst the few science-related career comments made, one HSC student wished to "be a cool doctor like House [a medical series]", whilst another observed that she liked "all that cool chemistry in CSI [a forensic science series]".

One student was interested to find, after surfing the net, that she could study both science and commerce: "Maybe I can do science and be rich!" Others students discussed that earning high salaries was also of high importance to them. Of the several IBD students who wished to travel, two were applying for overseas arts degree scholarships and one commented enthusiastically "I feel like the world is my oyster". These IBD students felt that international nature their chosen programme provided a qualification that offered many openings in this respect and correspond with the recent findings of Doherty et al. (2009) that the IBD attracts students with aspirations to be internationally mobile.

Concerning their school careers advice, none of the students on either programme felt that they had been given sufficient information about the range of science careers available, except in the field of medicine. When discussing the careers information service, one student commented "the only science career we really heard about was medicine, which is fine if you want to do that … but I wanted some other ideas" and another contributed "I looked up veterinary science on Google for information". The focus group interviews indicated that science careers information is an area that required improvement at Blackwood School.

5.4.5 Examination Success and University Admissions Index (UAI) Achievements

A further comparison of the two curricula was made using information related to student achievement. The next two sections examine student achievement in terms of their examination success and the University Administration Index (UAI) for each programme.

Examination Success

Although the IBD and HSC have different frames of reference, both combine internal and external assessment marks to provide a final grade. The Board of Studies (BOS) awards a percentage mark and Band (1-6) for each HSC subject and the International Baccalaureate Organisation (IBO) awards a mark out of 40 and a Band (1-7) for the total diploma. To provide a basis for comparison amongst Blackwood School students, the percentage of top scoring HSC science students were matched alongside the percentage of top scoring IBD Higher Level science students. These figures, in turn, were compared with the New South Wales state-wide results. For the HSC biology students at Blackwood School, 66% achieved the top two band levels (12% achieved the top level, Band 6 and 54% achieved the second level, Band 5), compared with 30% of the total biology candidature, state-wide, that achieved these standards. Twice as many biology students compared to chemistry students achieved the top State standard at Blackwood School. For the HSC chemistry students, 43% achieved the top two bands, 7% above the state-wide chemistry results.

No such statistics were available from the IBO so, in order to compare the achievements of the IBD students with the HSC students, the subject and level of attainment was examined. At the Higher Level, none of the students enrolled in either the biology or chemistry course attained marks within the top two bands.

However, at the Standard Level, 75% of the biology students and 40% of the chemistry students achieved a Band 5 equivalent. Table 5.3 illustrates this comparison.

Students involved in focus group interviews generally agreed that chemistry was more challenging and more difficult to understand than biology. These perceptions were reflected in the lower grades attained in chemistry. Despite the range of abilities, none of the students enrolled in HSC science courses attained less than a Band 3 (60-69%). These grades were consistent with previous year's achievements in biology and chemistry and compared well against the State average results.

Table 5.3: Comparison of the HSC, IBD Higher Level and State-Wide Achievement of Students for Chemistry and Biology

Top 20% Marks Awarded		Student achievement					
		Chemistry %			Biology %		
HSC Band	IBD Grade	School HSC	State HSC	School IBD	School HSC	State HSC	School IBD
6	7	4	9	0	12	8	0
5	6	39	27	0	54	22	0

For the IBD programme, teachers were required to submit an estimated grade from 1-7 for each subject to assist with moderation of the marks. The estimates provided by the two IBD teachers, Beryl and Christine, were higher than the final grades achieved by the students.

This comparison of grades between the science courses was significant as it demonstrates that, although the students were drawn from a similar pool, and have experienced similar learning environments, student achievement in the new IBD science programme was lower than their HSC counterparts. The following section provides further information related to students' achievement in science with respect to university admission.

University Admission Index

To gain a place at a university in New South Wales, students required a University Admission Index (UAI). The UAI calculation was complex and not readily available to the public. For the HSC programme, individual HSC marks for each subject were reviewed, and the best ten units (usually equivalent to four or five subjects) selected. Different subject weighting was then taken into account (science is generally weighted higher than arts subjects) and the marks compared with the state Year 10 School Certificate profile for the cohort. The UAI was then calculated to provide a final score out of one hundred (calculated to one decimal place) (University Admissions Centre, 2003). Effectively, the UAI score indicated the student's rank in their cohort, and enabled the student to gain access to a range of university courses, depending on the admissions level set at each institution. A direct comparison between the two programmes can be made using this index.

At Blackwood School eleven students completed the IBD and successfully qualified for a UAI. Students enrolled in IBD biology achieved an average UAI of 93.7 and those enrolled in IBD chemistry achieved an average of 96.3. Students enrolled in both biology and chemistry achieved an average UAI of 92.3. For students enrolled in the HSC programme, these differed somewhat. Students studying HSC biology achieved an average UAI of 78.3, those studying HSC chemistry achieved an average of 96.3, and students studying both biology and chemistry achieved an average UAI of 89.1. These results are tabulated in Table 5.4.

Table 5.4: Comparison of IBD Higher Level and HSC Student Achievement Based on the Average UAI Score

Subject	Average University Admissions Index (UAI)	
	HSC students	IBD students
Biology	78.3	93.7
Chemistry	96.3	96.3
Biology and chemistry	89.1	92.3

The results indicated that, although the IBD students achieved lower examination results in their science subjects than their HSC counterparts (Table 5.3), their overall UAI score was considerably higher (by up to 7 points). The final UAI would give the IBD students a considerable advantage over the HSC students when applying for tertiary course admission (the acceptance for which depends solely on the students' UAI score).

5.5 YEAR 10 PREPARATION FOR STUDYING SENIOR SCIENCE

This section is devoted to examining whether students considered their Year 10 programme to adequately prepare them for their Year 11 and 12 science courses. In New South Wales, students select their senior subjects in the middle of Year 10. In 2004, for the first time, Year 10 students at Blackwood School were required to select not only the subjects they would enrol in but also the senior programme, IBD or HSC. It was anticipated, by the science teachers at the school, that a student's decision to study science might reflect their experiences of science to date. In turn, this might also influence their choice of programme, as the study of science is compulsory within the IBD but not in the HSC.

To examine the adequacy of the year 10 programme in terms of preparing students and to provide information with which to enhance and improve the students' experience of science, the fifth aim was developed:

Research Objective #5

To investigate whether the Year 10 science programme provides an enjoyable experience and whether differences exist for students enrolled in IBD and HSC in terms of adequate preparation for their selected programme.

To address this objective, data were collected using a questionnaire developed by the researcher, informal focus group interviews with students, as well as interviews with teaching and administrative staff. This information was then triangulated and the results provided in two sections. Section 5.5.1 provides information about students' views of the Year 10 programme and section 5.5.2 examines students' views on the adequacy of the Year 10 preparation to aid a smooth transition into their senior level science course.

5.5.1 Students' Views of the Year 10 Science Course

Teachers of the Year 10 classes whom were interviewed, generally agreed that students' were more likely to select senior subjects that they had enjoyed science in

Year 10, a notion supported by Butler (2008). At the start of the study, when students were commencing their Year 11 studies, a questionnaire was administered to provide an overview of students' views of their Year 10 experience of science. Focus group interviews were used to provide reasons for the responses. This section examines students' views of their Year 10 science experience with respect to their enjoyment, perceived challenge of the course, whether the laboratory work was adequate and the opportunities for students to pursue their own interests or independent study.

Student Enjoyment

Because student enjoyment has the potential to influence their choice of science in year 11 and 12, this question was examined. Students' responses indicated that 60% of the students had enjoyed the Year 10 science course, out of which 40% enjoyed it very much. Focus group interviews suggested that students' enjoyment of science at the Year 10 level was one of the main reasons for choosing science subjects at the senior level. These positive comments were not generally in keeping with past studies into western teenagers' view of science courses which report generally negative attitudes towards course content and enjoyment in science (Schreiner & Sjøberg, 2007).

40% of the students reported that they did not enjoy their Year 10 science programme. 30% of these students elected to enrol in the IBD programme knowing that science was a compulsory component. Interviews indicated that many of these students were inclined to focus on a dislike of a particular teacher rather than the subject itself, suggesting that the enjoyment of the subject could be related to the relationships between the teacher and student. Informal interviews with Beryl and Christine indicated that they agreed that students were likely to choose a subject at the senior level because of the teacher involved rather than the subject.

Student Challenge

The Year 10 science course was largely content-based, despite the fact that the syllabus advocates problem-based learning (Board of Studies, 2003). Blackwood School was non-selective, and, in order to manage the range of abilities, the 135 Year 10 students were streamed into six classes according to the ability that they displayed in Year 9. When students enrolled in Year 11, they were asked whether they had found the Year 10 course to be challenging, and 70% of them agreed that it was. The Year 10 science staff expressed that they were encouraged by these results and felt that streaming the year group according to student ability increased the opportunity for teachers to successfully challenge the students in their class.

Focus group interviews revealed that students generally equated the term challenge with assessment tasks that they were required to complete. All of the students whom were interviewed complained about the number of assessment tasks, particularly the number of tests that they were required to take (one per topic). One student stated that these tests were "always held at the same time as other [subject] tests".

Laboratory Work

For both the IBD and HSC science programmes, laboratory work was considered to be an important aspect of science teaching. Given the emphasis placed on the laboratory work in each of the programmes (IBD and HSC), it was important that students have sufficient experience of practical work at the Year 10 level. To this end, students were asked whether they felt that they were provided with sufficient time for practical work and opportunities to pursue answers to their own science questions during their Year 10 programme. Student responses indicated that over 55% of students would have preferred more practical work during their Year 10 science course. During focus group sessions one student commented "Experiments made things easier to understand…like forces, you could see them happening. I would have liked to have done more". Another student commented "[the teacher] did most of ours [experiments] but I liked watching".

Interviews with these teachers indicated that although the Year 10 syllabus specified that 50% of class time should be spent on laboratory activities, this was not always practicable because of the large amount of content knowledge to be covered and the large class sizes. One of the case study teachers, Christine, noted that the 50-minute lessons were a constraint as this was insufficient time to enable students to collect meaningful data and to ensure that the laboratory was tidied.

Opportunities for Students to Pursue Individual Interests

Traditionally Blackwood School has concentrated on a more content-focused, teacher-centred approach to learning. The current Year 10 syllabus has a content-heavy framework and demands contextualisation and the inclusion of learning skills (Board of Studies, 2003).

As student choice had been identified as key to motivation (Kornhaber, 2004; McGrath & Noble, 2005) students were asked whether opportunities for personal input to the course exist. It was recognised that responses to this question were likely to depend heavily on the pedagogical style of their class science teacher; however it was felt that the laboratory work provided an ideal opportunity for individual design, ideas and development if time permitted. Student responses indicated that 50% of them felt that they had been given opportunities for personal investigation. Focus group interviews indicated that such opportunities were considered to be a positive aspect of students' Year 10 science experience. The data also suggests that the 50% of the students would prefer a more open-ended and practical experience of science. One student observed that "We were always told what to do. Yes it's hard having to think…but then I understand it better". In particular, two of the higher academic classes had been visited by a group of university engineering students who carried out laboratory challenge activities with the students. This experience was identified as a highlight during the focus group discussion.

Independent Study

Given the rigor and depth of the IBD program, students were required to be able to monitor and regulate their own progress, and hence develop skills that would prepare them for tertiary education. Therefore, the development of skills for independent study was considered, by the IBO, to be an important preparation for the IBD program.

Over the course of the Year 10 science programme homework was set for all classes on a regular basis. Higher ability classes were given more work and more challenging tasks. All students were expected to keep up-to-date with their study notes and activities, as the pace through the content-laden syllabus was demanding. Assessment tasks were generally differentiated to allow for the students to achieve to the best of their ability. The teachers, however, were of the opinion that the students relied too heavily on class notes and rote learning rather than understanding scientific concepts.

When questioned about the amount of homework that they were given during Year 10, 90% of the students surveyed felt that the amount of homework had been adequate while 10% indicated that more homework should have been set. Student discussions during a focus group interview suggested that other subject areas, in particular mathematics, demanded more homework than science, making the requirements of the science teachers appear light by comparison. When asked what type of additional homework these students would have liked, one commented "Science homework was always assignments or learning for tests … I would have preferred some experiments or something". Another commented "Tests were always hard I needed more practice in some of the questions. This could have been done at home". The teaching staff generally agreed that student results for the School Certificate in Science would improve if students were given more homework. In addition, the three teachers felt that more homework in Year 10 would give students a higher focus on independent study.

It would appear that, in general, students in both groups were satisfied with their Year 10 programme in terms of enjoyment and amount of challenge and independent study. Although many students were satisfied with the amount of laboratory work there was a percentage who felt that it would be advantageous to include more. Despite student enjoyment of the subjects, it was interesting to note that a student's like or dislike of a teacher could strongly influence a students' decision to pursue science in Year 11.

5.5.2 Students' Views of the Adequacy of the Year 10 Science Programme

To gain insights into students' views of how well the Year 10 science program had prepared them for their respective senior science courses, at the end of the two years students were asked: "Do you think that the Year 10 science course prepared you for your senior studies?" 80% of the HSC students agreed that the Year 10 course had helped them to prepare for their senior science studies. Of the students whom were interviewed, many commented that, in biology, the Year 11 course was “just a repeat of the junior work” but with more detail. This repetition was also observed by Heidi, the HSC teacher, who commented that “whilst this repetition is useful for the less able students who need to consolidate their Year 10 knowledge, the more able students needed new and challenging work”.

In contrast, the IBD students were unanimous in their dissent of the preparation provided by the Year 10 course. During the focus group interviews, students generally agreed that the Year 10 course was too basic, both in terms of the theory and laboratory work. One student commented that the Year 10 programme had “No depth at all, it only touched the surface of what we were to do”. Another student agreed that the Year 10 course was “…not detailed enough for the IBD [science programme]”. One articulate student stated “Although it provided a base of knowledge, specific IBD areas were not adequately covered in Year 10, which makes it extremely hard to adapt to the course in Year 11”. Some of these students felt overwhelmed and were identifying large gaps in their skill and knowledge base. In contrast, students enrolled in the HSC programme were finding that in revisiting and developing familiar topics studied during their Year 10 science lessons they were feeling confident in their studies and reported no anxieties.

The science teachers from both programmes agreed that the Year 7-10 curriculum was directed specifically towards students moving on to the HSC science programme and felt that it did not adequately prepare students intending to study the IBD science programme. During interviews, both of the IBD teachers, over the course of the two years, expressed concerns about the level of background knowledge that was expected by the IBD syllabus. As they started each new topic, the teachers identified the added complexity required by the IBD syllabus when compared with that of the HSC syllabus. For example, Christine, the IBD teacher explained that, the Year 11 HSC chemistry programme involved little more than the Year 10 science course, whereas the Year 12 HSC chemistry course included “additional equations that students need to learn to help to illustrate answers, such the as combustion of hydrocarbons”. However, she felt that “equations for the IBD chemistry course follow a more systematic format and can be more complex than the HSC chemistry course". Christine was of the opinion that "Some of the equations included in the IBD chemistry course were equivalent to first year university standard".

It would appear that, to maximise the opportunities for success of those students enrolled in both the HSC and the IBD programmes it would be beneficial to address these discrepancies in the extent to which students were prepared for their respective programmes during the Year 10 science course.

5.6 CHAPTER SUMMARY

This chapter made further comparisons of the two curricula by examining experiences of the participants and outcomes related to the two programmes. Using the second and third levels of Keeves' framework for curriculum analysis, the antecedents and context for the implemented curricula and the achieved curricula were described. The antecedents included the classroom conditions and student characteristics. Both groups were allocated the majority of their classroom time in well-equipped science laboratories. The class sizes for the HSC science programme where considerably larger (more than twenty) than the new IBD programme (less than 10). The allocation of laboratories was based on the size of classes, which meant that the HSC class was allocated the larger, older laboratory and the IBD classes were allocated the somewhat newer, smaller laboratories.

The context of the implemented and achieved curricula included age and cultural composition of the students in the two groups. In terms of student characteristics there were several differences between the IBD and HSC programme. The two programmes were open to all students, regardless of ability however, none of the IBD students were from the lower-ability stream and five students from this stream were included among the HSC students. The average ages of the two groups was slightly older than would normally be expected in New South Wales, because some students were from overseas and had spent a year learning English prior to admission to the school. The cultural composition of the two groups was similar, comprising students from Caucasian and Asian backgrounds.

Largely as a result of promotions carried out to encourage enrolments to the new IBD programme, the two programmes became viewed in different ways, the IBD as new and innovative and the HSC as familiar and safe. To encourage students in the IBD cohort, a camp, designed to encourage the students was held towards the end of the Year 10 programme.

Issues related to the delivery of the two science curricula were considered from the perspective of the three teachers involved. One of the major discrepancies between the two programmes was that the IBD science programme required greater depth of knowledge and understanding on the part of the teachers and the students. In contrast, teachers were of the opinion that the HSC demanded a greater breadth of knowledge and included the social and historical aspects of the syllabus. The IBD teachers felt that they would be better equipped to cope with the depth of knowledge required in the IBD programme, if they had acquired a specialist science degree prior to their teaching qualification.

Interviews with teachers indicated that the IBD science programme was less adequately resourced, in terms of support information and texts, when compared to the HSC science programme. In terms of resources, the main issue experienced by the IBD teachers was not related to funding but to access to relevant texts with the correct level of course content. Some advanced equipment would be needed, but the decision not to purchase immediately was made by the teachers who were keen to familiarise themselves with the programme prior to making such a large expenditure. A further issue associated with resources was class size. Lower than expected enrolments on the IBD programme resulted in comparatively large HSC science classes. These disparities in class sizes caused laboratory management and equipment challenges for the HSC classes.

The perceptions of the students', with respect to their learning environment, were compared to provide information about their experiences as the two programmes were implemented using the Science Laboratory Environment Inventory (SLEI; Fraser, Giddings and McRobbie, 1995). Statistically significant differences between the IBD and HSC students were found for three of the five scales, namely, Student Cohesiveness, Integration, and Material Environment. In each case the IBD students responded more favourably than their HSC counterparts. Focus group interviews indicated that the main factors influencing the differences in the Student Cohesiveness scale and the Integration scale was the smaller class sizes and holistic nature of the IBD programme. Interviews indicated that the difference between the perceptions of the Material Environment scale was related to the allocation of science laboratories. During these interviews with students it became apparent that students enrolled in the HSC programme were generally of the opinion that the IBD group was favoured within the school and was considered to be more elite. This sentiment was echoed by the IBD group also.

To provide an indication of the success of the achieved curricula of the two programmes, three aspects were considered. To provide an indication of the propensity that a student might have to for a science related career, the Multiple Intelligence Checklist for Adults and Senior Secondary students (MICA: McGrath & Noble, 2005) was administered. Examination of students' perceived strengths for those intelligences identified as having a strong scientific thrust indicated that there was no difference for either the HSC or IBD programmes. In addition, the low scores on these areas of intelligence suggest that none of the students would be inclined to pursue a science-related career. Students were asked at the beginning and end of the two year programme about their aspirations to provide an indication of whether they were the likelihood of selecting a science-related career changed over the duration of the two year programmes. At the end of the two years there was an increase in the number of IBD students and a decrease in the number of HSC students wishing to pursue a science-related career. This was interesting as science was compulsory subject for IBD students but not for HSC students. Focus group interviews also indicated that the career guidance afforded to students could be compounding the problems associated with students not selecting science-related careers as they complained of a dearth of information related to such careers.

A second measure of the success of the achieved curriculum was related to students' satisfaction with their science courses. The majority of students on both programmes enjoyed their experiences expressing that their programme had helped them to reach their potential in terms of achievement. During focus group interviews, IBD students were a little more anxious about their achievement than their HSC counterparts, but this was found to be because HSC students had received their internal assessment grade and the IBD students had no indication of their relative success.

As a final measure of success academic achievement was used to compare the two programmes. The final examination results indicated that the HSC students were more successful than the IBD students with more students achieving the top two band scores. However, based on the national University Admissions Index (UAI) scores, the IBD students did considerably better than their HSC counterparts.

The final section considered students' views of the Year 10 science programme and whether the programme adequately prepared them for their Year 11 and 12 science studies. Students' views of their science programme appeared to have some bearing on their selection of senior school science subjects but focus group interviews suggested that the teacher was also a strong influence on many students' decisions to select science. The HSC student group generally found that their Year 10 science course (specifically developed by the BOS as a precursor for HSC science subjects) to be good preparation for their senior studies whereas both the IBD students and staff found the standard to be lacking in depth and content.

The next chapter provides a discussion of the results and their implications for teaching and learning within the IBD and HSC science programmes at Blackwood School. It also includes an overview of the significance and limitations of the present study in addition to some implications of the findings and suggestions for future research.

CHAPTER 6

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

This thesis has reported the findings related to a two-year study undertaken during a period of significant change within Blackwood School when the IBD curriculum was introduced alongside the existing local curriculum. The overarching aim of the study was to compare and evaluate the two senior science curricula at an independent girls' high school in Australia, by examining the intended, implemented and achieved curriculum. This chapter concludes the study by providing a synthesis of the results drawing conclusions and examining the implications for further research.

The theoretical framework of the study, developed from the literature review, commenced from a more positivistic approach and moved to a more interpretive approach as the study progressed (Denzin & Lincoln, 1994). The design of the study and selection of appropriate research methods was set within Stake's (1976) responsive model for evaluating the curriculum. A mixed-method approach was used, combining qualitative and quantitative methods and using and modifying a selection of established models for curriculum comparison.

Three science teachers (two teaching the IBD programme and one teaching the HSC programme) participated in the study to provide a comprehensive view of the issues related to the teaching experience within Blackwood School. Two groups of science students also participated in the present study; one group was enrolled in the HSC and the other in the newly offered IBD. This study investigated students' perceptions of the learning environments created in each of the programmes, their views and opinions of their respective courses, their propensity and desire to pursue a science-related career, and their academic achievement. Importantly, the study examined students' and teachers' views of the suitability of the preparation provided by the Year 9/10 science curriculum offered at Blackwood (designed to lead into the HSC) and its relevance as a precursor to the IBD science courses.

Keeves' (2004) model provided a broad framework for the collection, analyses and representation of the data and placed the curricula within the wider context of the Australian education system and Blackwood School. To investigate the intended curriculum, Halls' model (1971) was modified to compare the content and aims of the two physics courses. Gilbert's (2004) model was then used to help to compare the skills to be taught within each programme. A range of documents, related to the two programmes, were used to help to inform the comparisons and the views of the participant teachers and students helped to substantiate the comparison.

To investigate the implemented curriculum, the views of teachers and students were sought. In depth interviews with teachers and classroom observations were used to illuminate the implemented curricula from the teachers' perceptions and highlighted issues related to teaching their respective programmes. Students' perceptions of the learning environment were used to provide an indication of whether the two curricula differed in this respect. To further examine the students' views of the implemented curriculum, focus group interviews with students were held at various intervals during the two years of the study.

The achieved curriculum for both programmes was examined in terms of students' propensity and desire for choosing a science-related career; enjoyment of their senior science course; and examination results. Both quantitative and qualitative data were collected. Purpose-designed questionnaires provided an overview of students' views while focus group interviews were used to provide deeper insights. The MICA was administered to provide an indication of students' propensity towards a science-related careers and a direct question, asking about their career aspirations at the beginning and end of the two-year programme provided an indication of students' career choice and whether these changed over this period. Again, focus group interviews were used to complement the questionnaires and to provide explanations for students' responses.

The summary, conclusions, limitations and recommendations are reported using the following headings:

6.1 Summary of Results;

6.2 Limitations of the Study;
6.3 Implications of the Study;
6.4 Significance of the Study; and
6.5 Recommendations for Future Research.

6.1 SUMMARY OF RESULTS

This section summarises the major findings of this comparative study including: the similarities and differences between the intended science curricula (discussed in Section 6.1.1); the views of the teachers (with respect to the implementation of the two curricula) (discussed in Section 6.1.2); views of the students (with respect to their experience during the implementation of their chosen programme) (discussed in Section 6.1.3); the achieved curriculum (discussed in Section 6.1.4); and student's views of their preparedness for their respective courses (discussed in Section 6.1.5).

6.1.1 Summary of Findings for Research Objective 1: Comparing the Intended Science Curricula

To compare the intended curricula, syllabus documents and website programme statements were used to examine the curriculum content, objectives and assessment of the HSC and IBD physics courses. The comparative analysis of the IBD and HSC science curricula, using syllabus documents, identified that, whereas the designated subjects and hours were similar, the philosophical framework, overarching aims and objectives were quite different. This section summarises the major findings.

In terms of the framework, the IBD curricular was designed to provide students with a holistic experience in which the study of an experimental science was just one of six compulsory academic groups. The HSC, on the other hand, provided students with a selection of unrelated subjects, of which only English was compulsory. To gain a university place an IBD student were required to successfully complete a full programme, whilst an HSC student was required to pass five subjects including English.

Students electing to enrol in the IBD program could select from two levels of study, the Standard Level and the Higher Level, whereas students who enrol in the HSC have only one level of study available to them within the science subjects. The IBD Higher Level science course was deemed to be equivalent to the HSC science course in terms of allocated teaching time and assessment length.

Time allocation for the various tasks (theory, practical and assessment) was different for each of the two programmes. The IBO (governing body for the IBD) stipulated the number of hours to be spent on theory, practical work and internal assessment, whereas the BOS (governing body for the HSC) recommended the time to be allocated to practical work, which was twice that of the IBD, and left the remaining class time to the discretion of the teacher.

To examine similarities and differences between the subject content, aims and objectives of the two curricula, a modified version of Halls' (1971) model was used. The results indicated that the IBD science curriculum had a more traditional and mathematical emphasis than the HSC science curriculum. It would also appear that the HSC science curriculum placed more emphasis on aspects related to historical development and to social contexts than the IBD science curriculum. In particular, Australian themes were featured.

The HSC science curriculum has replaced some of the more traditional topics with more recent theories, such as, the Theory of Special relativity. It is thought by many NSW physics teachers and university lecturers that some of these concepts were challenging for students to understand at this level of their education. Given that they are of interest to students, these subjects have been included to help to attract and engage students. The IBD, on the other hand, maintains more traditional topics, but has introduced some modern concepts into the optional topics at the Higher Level.

An in depth analysis of one topic, with respect to the required knowledge identified in the syllabus documents and its assessment in an examination, indicated that the IBD tends to require more depth to the study of subject content, whereas the HSC tended to require greater breadth of content. A further difference highlighted in the comparison was that the IBD programme was more holistic in nature, whereas the

HSC programme teaches each science subject in isolation. To complement the holistic approach of the IBD, a cross-science project is required to be completed by IBD students.

The aims and objectives of the science courses were analysed from the syllabus documents using Halls' (1971) model, the results of which reflected similar findings. The IBD documents reveal an emphasis on awareness of scientific practice and communication, whilst the HSC documents include these aims alongside those of knowledge of history, applications and social context.

To compare the skills identified in each curriculum, the Australian Council for Educational Research (2001) framework, as adapted by Gilbert (2004), was used, although on several occasions a broader interpretation of each skill was employed. As expected, these results reflect those included in the comparison of subject content, aims and objectives, with results indicating a strong mathematical emphasis throughout the IBD science curriculum and a strong social component throughout the HSC programmes. The IBO gives fewer directives with respect to which skills should be employed in each section of the syllabus content when compared with the HSC syllabus.

Using relevant documents related to each curriculum, the assessment methods of each science programme were compared. Both programmes involve an internal and external assessment component, which vary in type, procedure and value. For the IBD, internal and external assessment involves all of the content and skills taught over the two year course. For the HSC, however, only the content and skills taught during the second year of the programme is assessed. Analyses of various documents indicate that the internal assessments required for each of the programmes differ considerably. IBD students have laboratory activities that are required to be completed and assessed during the two year programme (worth 24% of their final grade). Unlike the IBD teachers, the HSC teachers are required to design their own assessment activities to assess content and skills (worth 50% of the final marks).

The external component of the IBD programme assessment was comparable to the external component of the HSC in terms of examination length, but the weighting

(76% as opposed to 50%) differed. This difference in weighting reflects the need for closer monitoring of the IBO candidature due to its international diversity, compared to the localised HSC pool of teachers and students in NSW. A comparison of examination questions for the IBD and HSC external examinations indicated that there were some distinct differences in formats. Examination questions in the IBD papers were generally more structured, and more likely to include questions consisting of several sections which build on conceptual knowledge and difficulty. This format supports the strong emphasis on mathematical content and mathematical skills included in the IBD science curriculum. The examination questions included in the HSC external examination tended to have a briefer, open style of question in which students were expected to demonstrate both knowledge and scientific literacy in an extended written response.

The marking procedures provided an interesting contrast. Due to the international context of the IBO, the IBD examination scripts are posted to IBO appointed markers around the world, who receive correct answer sheets. Whole papers are double marked and the marks are collected and collated by the IBO. In contrast, the BOS assembles hundreds of NSW teachers for each subject at one venue in Sydney. Small teams of teachers are allocated a question on which they agree to an answer format. Double marking takes place initially to moderate the individual markers and subsequent spot checks are made to ensure that standards are maintained.

In summary, although the intention of both of the programmes is to prepare students for tertiary education and they bear some similarities in terms of the length of the course, the content and assessment, closer scrutiny reveals substantial differences. The intended IBD science curriculum provides a two-level, traditional, academic science programme with a strong emphasis on mathematics and, largely due to its international nature, has a bias towards external assessment. In contrast, the intended HSC science curriculum provides a single level, less traditional and less mathematical course, with an emphasis on scientific literacy based upon historical and social contexts.

Having compared the intended curriculum in depth, it was meaningful to investigate the implemented curriculum at Blackwood School, taking into consideration the views of the participants. Both the teachers and students involved in the HSC and IBD science programmes at Blackwood School were examined and compared. These results are summarised in the next two sections.

6.1.2 Summary of Findings for Research Objective 2: Comparing the Implemented Curriculum from the Teacher's Perspective

A comparison of the wider curriculum was undertaken using Keeve's (2004) model, summarised in Table 4.1. This analysis identifies that whilst the educational antecedents were similar, differences were observed in the area of educational context. These differences were due primarily to the diverse origins of the two educational bodies, the IBO overseeing the IBD and the BOS overseeing the HSC. Low IBD programme enrolment impacted on the selected teachers, subject choice and hence affected the two student groups. The differences in the two educational bodies also impacted on the implemented curriculum at all levels, from focus, content and procedures, to the teachers' prior experience, and ultimately to student experience within the chosen programme.

The issues related to the delivery of the IBD and HSC science curricula were considered from the perspective of the three teachers that were involved. Three main themes were identified, these being, a discrepancy between the depth of knowledge required for the respective programmes, the pressure of covering content and time management and the resources available.

It was interesting to note that the teachers on both programmes identified difficulties related to the delivery of extensive syllabus content and laboratory sessions and the pressure of covering these in addition to the assessment tasks. The IBD teachers (both of whom had taught the HSC syllabus for many years) agreed that the IBD science programme required a greater depth of knowledge and that the HSC required a greater breadth of knowledge. The IBD teachers identified the depth of knowledge required in the science syllabus as a major challenge, which lead to increased work pressure as they grappled to come to terms with the requirements. This was an issue that was also identified by Mathews and Hill (2005). In contrast, the HSC teacher felt informed and well supported by local networks.

All of the teachers identified the available resources as an issue, however the nature of the problem associated with resources differed for teachers on each programme. The IBD teachers identified that their syllabus required more technical equipment and course content information than was currently available. Whereas, the HSC teacher's needs were not related to subject support, but to the need for additional resources that would help to alleviate the pressures of a large class size, created as a result of the low enrolment on the IBD programme.

6.1.3 Summary of Findings for Research Objective 3: Comparing the Implemented Curriculum from the Students' Perspective

To examine the students' perspectives of the implemented curriculum, their views of the learning environment created on each programme were examined. Given the importance of the laboratory component of any science programme can be considered integral to the success of the programme students' perceptions of the laboratory learning environment were examined using the Science Laboratory Environment Inventory (SLEI; Fraser, Giddings & McRobbie, 1995). The results indicated that significant differences between the learning environment in the IBD and HSC learning environments existed for three dimensions, namely, Social Cohesiveness, Integration and Material Environment scale.

The Student Cohesiveness scale was concerning with the social relationships developed. Although, this was reasonable strong for both groups of students the results indicated that the HSC students identified the small IBD group as privileged in terms of both the resources allocated and the school's attitudes towards them. This perception of being an elite group also was acknowledged by the IBD students and was considered to be a strong contributing factor (in addition to the amount of time spent together) to the more favourable views of students' cohesiveness. This attitude of elitism in the IBD is well documented in other studies (Bagnall, 1994; Mathews & Hill, 2005).

The results indicated that the IBD students felt that the extent that theory and laboratory work were integrated was greater than their HSC counterparts. It was interesting to note, however that the IBD students did not always appreciate the high levels of integration, who perceived it as a distraction from the theory rather than a support. The HSC students would have preferred more integration, but this was counterbalanced by their teacher's concerns over management of the large group. Most of the students expressed a preference for more practical work in their respective science classes.

Students' responses to the Material Environment scale again exposed the resentment that HSC students felt towards the IBD group. Many of the HSC students felt that they were disadvantaged with respect to their allocated laboratory and other resources. However, whilst they were not disadvantaged in terms of equipment and facilities, there were disparities in terms of class size. The IBD students were content with their laboratory allocation and, having a small class size, there was adequate equipment for standard experiments.

The results indicated that having a different curriculum did indeed change the learning environment perceived by students (Walberg, 1970). It would appear, however that this change was related to the implemented curriculum rather than the intended curriculum. Student relationships within each of the science groups were strong, but for the IBD students, relationships were somewhat stronger, due largely to the amount of time that the students spent together. Of concern was the wider problem identified by HSC students who felt that their programme was considered, by the school, to be inferior.

6.1.4 Summary of Findings for Research Objective 4: Comparing the Achieved Curriculum

As an indication of the success of the achieved curricula for the two programmes, three aspects were considered: students' propensity and desire to pursue a science-related career; students' satisfaction with their science course; and academic achievement. The major aim of the HSC and IBD science programmes was to provide students with the skills and the desire to pursue a career in science. The Multiple Intelligence Checklist for Adults and Senior Secondary students (MICA; McGrath & Noble, 2005) was used to identify whether students had the propensity to pursue a science-related career. The results indicated that about one-third of students in the HSC science programme perceived themselves as having strengths in one of the three intelligences identified as having a strong scientific thrust, whilst the students enrolled in the IBD science programme showed little in the way of strength in any of these areas. It would appear that students' interpretation of various items of the MICA was influenced by factors other than their perceived strength in a particular intelligence area (e.g. confidence in mathematics was influenced by the level of mathematics that they were enrolled in). These findings indicated that, whilst the MICA might be useful in helping students to identify particular learning style, it was not a good indicator of a student's propensity towards a science-related career.

Students' responses to a question related to their career aspirations indicated that, at the beginning of the two years, more HSC students aspired to pursue a science-related career then their IBD counterparts and at the end of the two years, more IBD students aspired to a science-related career. These results were considered notable as science subjects were optional for the students enrolled in the HSC programme but compulsory for the students enrolled in the IBD programme. Further research is recommended to explore the possibility of a compulsory science subject, at the senior school level to attract students to science-related careers.

Student satisfaction with their respective science programme was gauged by questioning the students' enjoyment of their experience, and reviewing their perceptions of their achievement, views of their science course, and university and career opportunities. All except one of the students, an IBD girl, expressed that they had enjoyed their chosen course. Areas of dissatisfaction emerged, relating to the lack of subject choice within both programmes due to the cancellation of low demand subjects. This issue was exacerbated by the low IBD enrolment.

Students in both programmes felt that the demands of their science coursework were high. Some HSC students acknowledged that the IBD included content and skills that were of a higher academic level than the HSC science course. The results also indicated that the IBD students had less pressure than the HSC students in terms of internal assessments, but this resulted in a perceived lack of guidance obtained by the progress marks. With respect to their perceived potential of their course to provide university and career opportunities, both groups of students were confident. The IBD students maintained confidence, despite university admissions advice, provided at the end of the two years, being focused on the HSC qualifications.

As a final measure of success of the two programmes, the academic achievement of the two groups was used. Examination success for science gained by the students involved in the study, particularly the HSC students, was pleasing. Despite the higher examination marks, the IBD students were given higher standing than the HSC students in the UAI grading process, such that the IBD students attained higher UAI scores overall. These results were most confirming for the first IBD student cohort, their teachers and the school management.

6.1.5 Summary of Findings for Research Objective 5: Student's Views of their Preparedness for their Respective Courses

A further concern raised by science teachers at the start of the study was whether the Year 10 programme would adequately prepare students for the study of senior science for both programmes. The findings indicate that students on both programmes generally enjoyed their Year 10 science experience and found it challenging, although they would have preferred more practical work. At the end of their two year programme, IBD students expressed that the Year 10 programme had not been good preparation for their senior science source, a view that was echoed by the teachers involved in the study. In contrast, the HSC students reported that their initial study in Year 11, particularly for biology, repeated much of what was taught in the Year 10 programme. It would appear that, to better prepare students for the IBD programme, the Year 10 science programme will need to be examined.

6.2 LIMITATIONS OF THE STUDY

The sample size of the present study included three teachers and two groups of students (one studying the HSC and the other studying the IBD) in one independent girls' high school in New South Wales. The small sample size, largely the result of enrolments on the IBD programme limits the range of possible answers, so generalisation of the results to other populations should be made with caution.

Initially it was intended that I be a participant observer, documenting my views on the implementation of the IBD programme as I taught physics. However, due to low enrolments in the IBD programme, the physics programme was not offered, and I was required to change my role to a more passive observer. Moreover, physics, the subject analysed for the intended curricula, was not able to be part of the final study. This change of role, however, possibly helped to reduce possible influence or 'bias' within the study.

A further, possible limitation could have been created because of a power relationship that existed between myself, the science coordinator, and the three teachers involved. However, I had a good working relationship with two of the three teachers (one teaching the IBD science programme and the other teaching the HSC science programme), both of whom expressed that they considered my position not to be a barrier. It would appear from the reluctance of the third teacher, demonstrated by her inability to attend many of the interviews, that this may have been an issue.

A possible limitation was related to my status as a science teacher at the school as this could have influenced the comments of the students, introducing bias to the findings. However, because I was not teaching any of the students involved in the study the power relationship issue was minimised. As such, this study was more impartial than it might otherwise have been, thereby increasing its validity.

It was noted that a limitation of the curriculum content study was that a frequency count of topics or skills included in a unit of study can reflect a political rather than educational agenda.

A final limitation was related to the data used to examine students' academic achievement. As only the most successful students (with permission) and top groups of students had their results made public by the school, only general overviews and average percentages were used.

6.3 IMPLICATIONS OF THE STUDY

The insights gained from the present study provide implications for Blackwood School (discussed in Section 6.2.1) and for other schools wishing to introduce the IBD alongside a local curriculum such as the HSC (discussed in Section 6.2.2).

6.3.1 Implications for Blackwood School

For Blackwood School, the implications for the present study are related to the use of the information gained from the curriculum comparison, teacher-related issues, (including the need for professional development), and the views of the student groups in relation to their treatment by the school.

- The detailed comparison of the science courses within the two programmes can be used by Blackwood School to help to inform students and parents as to the distinctiveness and merits of the two programmes. This will assist the students and their parents in making informed decisions about the selection of senior education subjects.

- Given that all of the teachers involved in the study considered the issue of depth and breadth of knowledge to be an issue, professional development for teachers on both programmes may assist in managing these issues. It is recognised that, although the International Baccalaureate Organisation provided annual conferences with subject-based workshops, these were a high-cost option that do not necessarily cater for low-enrolment subjects, such as chemistry. The IBD science teachers felt that they needed assistance to deal with the deeper course content required by this programme as well as training to help them to use the more advanced equipment. It was also felt that issues of time management could also be addressed with subject-specific professional development.

- In terms of resources, the findings indicate that inadequate resources related to the IBD programme were considered to be an issue for the teachers. Since the data were collected, the IBD has started to produce texts and supporting documents to assist teachers and it would be advantageous for teachers have access these.

- A further issue related to resources was that of class sizes. The findings indicate that large class sizes were created as a result of the low IBD enrolment numbers. Addressing the issue of large HSC class sizes would ensure a safer laboratory environment with increased opportunities for student participation and more regular practical lessons.

- The findings of the study clearly identified the higher level of academic depth and rigor demanded by the IBD programme. The results indicated that there were a small number of students who were dissatisfied with their selection of programmes. In one case, the results indicated that a student, enrolled in the IBD programme, may have been better suited to the less rigorous HSC programme. The results also suggested that two students were insufficiently challenged by the HSC programme and might have been better suited to the IBD programme. These findings suggest that careful counselling may need to be introduced to ensure that students select the programme most suited to their ability.

- A repetitive theme that emerged throughout the study was the view of many HSC students that the IBD group was considered, by the school, to be favoured and more elite. These views could have emanated from a response to a strong marketing campaign and the desire by the school to ensure that this new group of students felt supported in their choice of programme. It would be advantageous for the school to address this perceived inequity as the results indicated that it created an unhealthy rivalry and a feeling of inferiority among the HSC students.

- Finally, the findings of the study suggest that students wishing to join the IBD programme would benefit from extension work. This might need to be provided for Year 10 science students wishing to join the IBD programme, in order to give them adequate grounding.

- The results of the study indicated that, when selecting courses for higher education at the end of Year 12, many of them were unaware of the range of science-related careers available. To encourage students to select science-related careers, increased liaison with the careers teacher would serve to ensure that students receive full and correct information related to a range of science-related opportunities.

In summary, it is recommended that Blackwood School provide students and parents with information as to the distinctiveness and merits of the two programmes, and individual counselling where needed, to assist in appropriate choice. The perceived inequity within the two programmes should also be addressed, both from the student and teacher perspective, particularly concerning the health and safety issue due to the inequalities of class size in science subjects. That the IBD teachers should be given targeted professional development and resources to assist their deeper understanding of knowledge and pedagogies required by the IBD. This would also involve developing the Year 10 science programme to prepare the students adequately. Finally, to address the careers information opportunities available for the students with respect to science careers.

6.3.2 Implications for Other Schools Looking to Introduce the IBD alongside the Local Curriculum

The results of the study also provide a number of implications for other school, looking to introduce the IBD alongside the local curriculum.

- A major issue highlighted by the teachers who were teaching the IBD science programme was the depth of knowledge required, a point identified in past studies (Daniel & Cox, 1992; Mathews & Hill, 2005; National Research Council, 2002). It should be noted that one of these teachers was of the opinion that her science qualification was of benefit to her as it provided a greater depth of knowledge that an education degree with a science major might otherwise have offered. This teacher was clear that her qualification was advantageous, a point that has been highlighted in other studies (Daniel & Cox, 1992; Mathews & Hill, 2005). Schools introducing the IBD would be advised to consider the advantages (to both the teacher and the students) of employing teachers who hold a science-related degree relevant to the subject that they are being employed to teach.

- Schools embarking on the introduction of the IBD would be advised to address the issue of suitable professional development of teachers. This was considered to be a major issue to the teachers at Blackwood School, who felt that their inadequate background caused considerable pressures to their workload. The findings of the study indicated that teachers should be prepared to spend considerable time in preparation and familiarising themselves with traditional topics, rigorous examination questions and the complex administration processes for practical assessments.

- A further implication of the findings of the study is related to the resources available for the new programme. Science teachers at Blackwood School were unwilling to outlay a large sum of money without having experienced the new curriculum. This was to prove somewhat detrimental to the the initial implementation of the new programme as the existing equipment was found not to be sufficiently advanced. The findings would suggest that, schools implementing the programme for the first time should seek the advice of other schools who have implemented the IBD to find out what equipment would be most useful.

- The findings of the present study indicate that the Year 10 course does not adequately meet the needs of the students' enrolling in the IBD programme. Blackwood School and other schools seeking to introduce the IBD would be advised to address any possible shortcomings in the programme to ensure that these students are adequately prepared.

In summary, it is recommended that science teachers selected for the IBD have a subject specific degree and that schools address the level of investment necessary for the professional development of teachers and resources required by the programme. It is also paramount that the Year 10 programme content and skills are developed so that shortcomings are addressed and that the students can be prepared for the more rigorous level of study.

6.4 SIGNIFICANCE OF THE STUDY

This study contributes to the field of science education in two ways. First, the study has five objectives with which it intended to inform the teachers and administrators of Blackwood School to improve both the delivery and teaching and learning of science within the two programmes. Second, the outcomes may usefully inform other schools who might be following a similar path or wish to emulate it.

A review of literature indicated that there is a dearth of studies related to curriculum comparison on science. This study contributes to the wider field of literature on curriculum comparison, particularly in the area of senior high school science. In comparing the international curriculum of the IBD and an Australian State curriculum the study complements the few similar studies in the USA where the IBD is generally compared with the Advanced Placement programme (Mathews & Hill, 2005; National Research Council, 2002). The study also builds on an earlier comparative study in Australia which investigates the introduction of the IBD into Australian schools with high schools in Canada with respect to its international perspectives (Bagnall, 1994).

The present study contributes to the vast field of learning environments by using the SLEI to compare students' perceptions of the laboratory experiences within two separate curricula, one state and one international, within one independent Australian school. Supported by qualitative findings the study identifies that, even though the intended curriculum of the two programmes have many similarities, the perceptions of the students' can be quite different within their micro learning environment in the implemented curriculum.

The present study adds to the growing literature related to implementing an international curriculum alongside the local curriculum. Information provided in this thesis could be used to help to inform government officials and policy makers with respect to introducing a national curriculum in Australia.

The results reported in the present study indicate that the Year 10 science programme, developed as a precursor to the HSC science curriculum, may not adequately prepare students for a different curriculum. These findings may help to inform curriculum developers and policy makers as they make decisions about a national curriculum.

6.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The results of the present study indicate the possibilities of successfully implementing two parallel curricula in the one school. In this case, the IBD and HSC were run consecutively within one well resourced, independent girls' school. The results indicate that whilst the intended syllabi of the IBD and HSC have different emphases they both address the needs of tertiary science education adequately. This section addresses the recommendation for future research.

The results of the research reported in this study indicate that there is much promise for the IBD when implemented alongside a local curriculum. The sample for the present sample however was limited. Future research could consider examining the adoption of the IBD in a school with a larger sample that is running the IBD alongside the local curriculum. For comparison purposes, now that more Australian schools are starting to adopt the IBD programme, a similar study could be undertaken within a NSW school having a larger IBD enrolment, such that a larger sample size might be available. A wider reaching comparative study involving other IBD schools might identify similar or different issues and parameters than those arising from Blackwood School.

Although the MICA was found not to be useful in the present study, the results of past studies with adults have suggested its usefulness in a range of areas. Further involving the modifying, validation and use of the MICA at the high school level could prove useful.

In summary, recommendations include extending the findings by using a NSW school with a larger IBD cohort. A wider study comparing another Australian state curriculum with the IBD could provide further insights to inform school and parental choice, and might further provide the Australian National Curriculum Assessment and Reporting Authority with a benchmark for further curriculum developments.

6.5.1 Concluding Remarks

Several facets of the present study have revealed areas of success and areas for improvement within the delivery of the two science programmes at Blackwood School. Success emerges from a variety of sources. First, that from an informed view the relative strengths of the two syllabi can now be articulated. Second, the majority of science students, within both programmes, are ultimately pleased with their choice of programme, enjoyed their science experience during it, and achieved good results. Finally, there is an overall increase in students considering a science-related career despite international trends.

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SCIENCE LABORATORY ENVIRONMENT INSTRUMENT (Fraser et al., 1989)

*Remember you are describing your **actual** classroom*	Almost Never / Seldom / Sometimes / Often / Very Often	For teacher's use
1. I get on well with students in this laboratory class	1 2 3 4 5	____
2. There is opportunity for me to pursue my own science interests in this class	1 2 3 4 5	____
3. What I do in our regular science class is unrelated to my laboratory work	1 2 3 4 5	R____
4. My laboratory class has clear rules to guide my activities	1 2 3 4 5	____
5. I find that the laboratory is crowded when I am doing experiments.	1 2 3 4 5	R____
6. I have little chance to get to know other students in this class	1 2 3 4 5	R____
7. In this class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	____
8. The laboratory work is unrelated to the topics I am studying in my science class.	1 2 3 4 5	R____
9. My laboratory class is rather informal and few rules are imposed on me.	1 2 3 4 5	R____
10. The equipment and materials I need for the laboratory activities are readily available.	1 2 3 4 5	____
11. Members of this laboratory class help me.	1 2 3 4 5	____
12. In my laboratory sessions, other students collect different data than I do for the same problem.	1 2 3 4 5	____
13. My regular science class work is integrated with laboratory activities.	1 2 3 4 5	____
14. I am required to follow certain rules in the laboratory.	1 2 3 4 5	____
15. I am ashamed of the appearance of this laboratory.	1 2 3 4 5	R____
16. I gat to know students in this laboratory class well.	1 2 3 4 5	____
17. I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	____
18. I use the theory from my regular science class lessons during laboratory activities.	1 2 3 4 5	____
19. 19. There is a recognized way for me to do things safely in this laboratory.	1 2 3 4 5	____
20. The laboratory equipment which I use is in poor working order.	1 2 3 4 5	R____
21. I am able to depend on other students for help during laboratory classes.	1 2 3 4 5	____
22. In my laboratory sessions, I do different experiments than some of the other students.	1 2 3 4 5	____
23. The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R____
24. There are few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R____
25. I find that the laboratory is hot and stuffy.	1 2 3 4 5	R____
26. It takes me a long time to get to know everybody by her first name in this class.	1 2 3 4 5	R____
27. In my laboratory sessions, the teacher decides the best way for me to carry out the experiments.	1 2 3 4 5	R____
28. What I do in laboratory sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	____
29. The science teacher outlines safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	____
30. The laboratory is an attractive place for me to work in.	1 2 3 4 5	____
31. I work cooperatively in laboratory sessions.	1 2 3 4 5	____
32. I decide the best way to proceed during laboratory experiments.	1 2 3 4 5	____
33. My laboratory work and regular science class work are unrelated.	1 2 3 4 5	R____
34. My laboratory class is run under clearer les than my other classes.	1 2 3 4 5	____
35. My laboratory class has enough room for individual or group work.	1 2 3 4 5	____

For teacher's use only: SC____ OE____ I____ RC____ ME____

MULTIPLE INTELLIGENCE CHECKLIST FOR ADULTS AND SENIOR SECONDARY STUDENTS (MICA) (Mcgrath & Noble, 2005)

		Very True of Me	**Somewhat True of Me**	**Not True of Me**
1	I am a well coordinated & feel confident that I can make my body do what I want it to do	3	2	1
2	I write well & I can usually find the right words to say what I mean & communicate my ideas	3	2	1
3	I have a good 'ear for music & can usually tell when a note is off-key or someone is singing or playing incorrectly	3	2	1
4	I like to spend time in bushland & I see details in insects, plants & trees that others miss	3	2	1
5	I am good at analysing how each person is different & their personalities, motivations & strengths	3	2	1
6	A Job I would be good at is one with quite a lot of writing & writing to do	3	2	1
7	I can successfully read maps& use them to find my way around. I have a good sense of direction & rarely get lost	3	2	1
8	I find it relatively easy to do practical maths in my head (eg. calculating costs/change & amounts)	3	2	1
9	I am good at finding the logical flaws & inconsistencies in arguments & ideas	3	2	1
10	Music is an important part of my leisure time. I listen to it a lot & go to musical concerts when I can	3	2	1
11	I am able to differentiate between many different insects, birds or animals because I observe a lot	3	2	1
12	People often come to me to talk about their problems & for personal advice	3	2	1
13	I know a lot about myself & I understand my own behaviour & feelings pretty well most of the time	3	2	1
14	I am good at miming & playing charades	3	2	1
15	I often notice small visual details that other people don't see & I remember visual details well	3	2	1
16	After something has upset me I try to understand my reactions and find ways to calm down & deal with it	3	2	1
17	I am good at imagining how something will look before I make it (eg. Renovations, designs, models, clothing)	3	2	1
18	I can recognise & name many trees & plants	3	2	1
19	I am good at working out how I am both similar to & different from other people I know & meet	3	2	1
20	English & languages are (were) my favourite subjects at school & I do (did) well in them	3	2	1
21	I am very sensitive to other people's feelings. I can usually 'read' how they are feeling & help where needed	3	2	1
22	Maths & Science are (were) among my favourite subjects at school & I do (did) well ion them	3	2	1
23	A job I would be good at is one that involves using my body or hands	3	2	1
24	I am good at deciding on a goal, working out how to do it, then persisting till I achieve it	3	2	1
25	I could learn most new sporting, exercise or dance skills pretty easily if I chose to	3	2	1
26	I like & am good at word puzzles & word games	3	2	1
27	I take part in art, design or craft activities or lessons in my leisure time & I am quite good at them	3	2	1
28	When I was younger I had a very strong interest in nature & I collected specimens or raised animals or birds	3	2	1

		Very True of Me	Somewhat True of Me	Not True of Me
29	I have a very strong interest in music & I have always been good at learning new songs & tunes	3	2	1
30	I am good at brainteasers, maths puzzles & playing strategic games like chess & Mastermind	3	2	1
31	I am skilled at using grammatically correct sentences & I have an extensive general vocabulary	3	2	1
32	I am good at working out which elements, when combined, form different styles of music (eg. Country, classical, rock)	3	2	1
33	I am good at working with my hands to make things (eg. carpentry, sewing, model building, origami)	3	2	1
34	I am a good speller & I take pride in spelling words correctly	3	2	1
35	Animals usually respond well to me because I have a natural affinity with them & care about them	3	2	1
36	I tend to take on the role of organiser when I am around others. I do it pretty efficiently & others respond well to me	3	2	1
37	I am a very keen reader in my leisure time & I read quickly and fluently	3	2	1
38	A job I would do well is one that involves either handling maths/numbers or doing scientific analysis or research	3	2	1
39	I know how to play a musical instrument & I have shown some talent at it	3	2	1
40	I can successfully adjust my behaviour so that I can get along well with a wide variety of people	3	2	1
41	I can quickly recognise familiar songs even when they are differently orchestrate or without words	3	2	1
42	I am good at logical thinking & argument of the kind used in debates	3	2	1
43	A job I would be good at is one that involves working with nature in some way, eg. A forest ranger, vet, marine biologist	3	2	1
44	I have spent a lot of my leisure time doing sport or other forms of physical activity & I am reasonably good at it	3	2	1
45	I am good at acting in plays & I can effectively communicate a character to an audience	3	2	1
46	I can accurately identify my strengths & weaknesses & predict how good I will be at something	3	2	1
47	I have a good sense of design & can work out which things look better & why, & which things go well together	3	2	1
48	I am good at showing & teaching others how to do things & I would do well in a job where I had to do a lot of that	3	2	1
49	Art or graphics or technical drawing is (was) a favourite subject at school & I do (did) well in it	3	2	1
50	I am motivated to find out about myself & I do quizzes or read books to improve my self-knowledge	3	2	1
51	I can 'see' a situation more readily if I can measure, count, categorise or analyse the material	3	2	1
52	I can usually work with small parts to fix things because I have good control over my hands & fingers	3	2	1
53	I am skilled at growing things - they mostly thrive	3	2	1
54	I can see clear visual images in my head of the things I am thinking about or remembering	3	2	1
55	I sing reasonably well & I can 'carry a tune' & sing harmoniously with others	3	2	1
56	I like to write down my experiences & my reactions to them so that I can reflect & learn from them	3	2	1

Enter the number you circled in the chart below to create your Relative Strengths Profile across the eight intelligences.					
	Question Number			**Question Number**	
Word Intelligence		**Score**	**Space & Vision Intelligence**		**Score**
	2			7	
	6			15	
	20			17	
	26			27	
	31			47	
	34			49	
	37			54	
	WORD TOTAL			**S & V TOTAL**	
Music Intelligence	3		**People Intelligence**	5	
	10			12	
	29			21	
	32			36	
	39			40	
	41			45	
	55			48	
	MUSIC TOTAL			**PEOPLE TOTAL**	
Logic/Maths Intelligence	8		**Body Intelligence**	1	
	9			14	
	22			23	
	30			25	
	38			33	
	42			44	
	51			52	
	L & M TOTAL			**BODY TOTAL**	
Naturalist Intelligence	4		**Self Intelligence**	13	
	11			16	
	18			19	
	28			24	
	35			46	
	43			50	
	53			56	
	NATURALIST TOTAL			**SELF TOTAL**	

Relative Strengths Profile Chart	**ORDER**	**Your total score**	**Intelligence**
	1st		
Write your scores for each	2nd		
intelligence in order from highest (1st)	3rd		
to lowest (8th)	4th		
	5th		
Use a bracket to indicate identical	6th		
scores	7th		
	8th		

APPENDIX C
INITIAL QUESTIONNAIRE

YEAR 11 IB / HSC COURSE – INITIAL VIEWS

Please read the statements carefully and circle the number closest to your view.
Please feel free to comment.

1. I am on the IB ☐ HSC ☐ programme, studying Biology ☐ Chemistry ☐

2. I am on this programme because:

	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
I discussed the choice with my parents and they wanted me to join it	1	2	3	4	0
I discussed the choice with my parents and I wanted to join it.	1	2	3	4	0
I did not know there was a choice.	1	2	3	4	0

Comment:

3. I think that this programme will offer me:

More variety of subjects	1	2	3	4	0
More depth in the subjects	1	2	3	4	0
Better university opportunities	1	2	3	4	0
Better career opportunities	1	2	3	4	0

Comment:

4. I am most looking forward to…

5. I am most concerned about…

VIEWS OF YEAR 10 SCIENCE

Please read the statements carefully and circle the number closest to your view. Please feel free to comment.

Your views on your science course:	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
1. I enjoyed the majority of the topics taught	1	2	3	4	0
2. I thought the amount of laboratory work was about right	1	2	3	4	0
3. I would have liked to carry out more laboratory work	1	2	3	4	0
4. I was given opportunity to explore my own science questions	1	2	3	4	0
5. The amount of homework set was about right	1	2	3	4	0
6. I carried out extra study on my own to help my understanding	1	2	3	4	0
7. I carried out extra study on my own because I was interested	1	2	3	4	0
8. The course challenged me	1	2	3	4	0
9. I am considering a career in a science related field	1	2	3	4	0
10. I would have liked more information on science careers	1	2	3	4	0

Comment:

FINAL QUESTIONNAIRE

YEAR 12 IB / HSC COURSE – FINAL VIEWS

Please read the statements carefully and circle the number closest to your view.
Please feel free to comment.

1. I am on the IB ☐ HSC ☐ programme, studying Biology ☐ Chemistry ☐

2.

	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
I have enjoyed this programme	1	2	3	4	0
I wish I had chosen the other programme	1	2	3	4	0
I have done as well as I thought I would	1	2	3	4	0
I think I would have done better on the other programme	1	2	3	4	0

Comment:

4. I think that this programme has offered me:

More variety of subjects	1	2	3	4	0
More depth in the subjects	1	2	3	4	0
Better university opportunities	1	2	3	4	0
Better career opportunities	1	2	3	4	0

Comment:

4. I most enjoyed…

5. I have been most concerned about…

Please read the statements carefully and circle the number closest to your view.
Please feel free to comment.

Your views on your science course:	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
1. I enjoyed the majority of the topics taught	1	2	3	4	0
2. I thought the amount of laboratory work was about right	1	2	3	4	0
3. I would have liked to carry out more laboratory work	1	2	3	4	0
4. I was given opportunity to explore my own science questions	1	2	3	4	0
5. The amount of homework set was about right	1	2	3	4	0
6. I carried out extra study on my own to help my understanding	1	2	3	4	0
7. I carried out extra study on my own because I was interested	1	2	3	4	0
8. The course challenged me	1	2	3	4	0
9. I am considering a career in a science related field	1	2	3	4	0
10. I would have liked more information on science careers	1	2	3	4	0

Comment:

Do you think that the Year 10 science course prepared you for your senior studies?
YES/NO
Please give details.

APPENDIX D

LETTER TO PARENTS

Dear Parents,

I am currently studying for my Doctorate in Science Education at Curtin University of Technology, and your daughter has been chosen to take part in my current research project. This project will examine and compare the curriculum issues involved within two different programmes of study. One is the traditional Higher School Certificate and the other is the International Baccalaureate Diploma which being offered as a new programme. The systems of delivery and assessment of Science within the two programmes will be investigated and compared. This will provide information from which to improve the delivery and assessment of all our Science courses in the future. The experience and views of each of student will be sought and analysed so that comparisons between the two programmes may be made.

Participation is voluntary. I would like to assure you that full confidentiality will apply throughout the study and anonymity will be maintained in any material produced from the research. All interviews for the collection of data will take place at the student's convenience and will take the form of both questionnaire and informal discussion.

Your daughter will be able to withdraw from the study at any time should she or you chose. Any decision to participate or otherwise will have no impact at all on your relationship with Blackwood School for Girls.

If you are willing for to be part of the research group and participate in the study please indicate your permission by signing the slip below and returning it to me or the School Office by

Please do not hesitate to contact me if you would like to discuss this further on xxx

Yours sincerely,

Alexandra Hugman
Science Coordinator

I give permission for my daughter ……………………………………… to take part in the Comparative Science Programme study

Signed ………………………………………………   Date…….

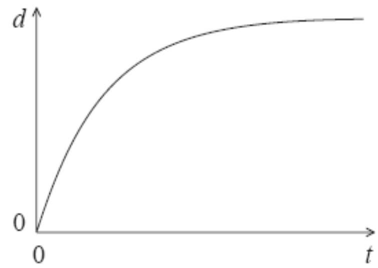
APPENDIX E

EXAMINATION QUESTIONS

MULTIPLE CHOICE QUESTIONS

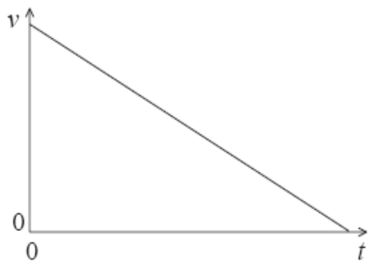
Excerpt from the IBD, November 2006 Advanced Level Paper 1 examination.

The graph below shows the variation with time *t* of the displacement *d* of a body moving alc straight-line.

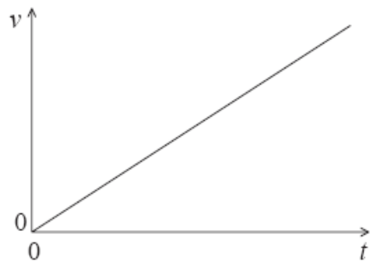


Which graph best represents the variation with time *t* of the velocity *v* of the body?

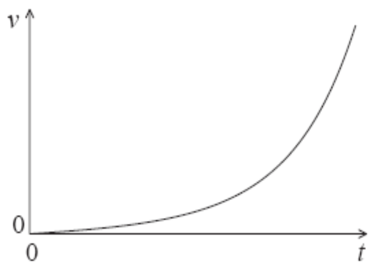
A.



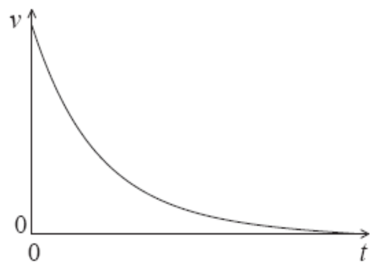
B.



C.



D.



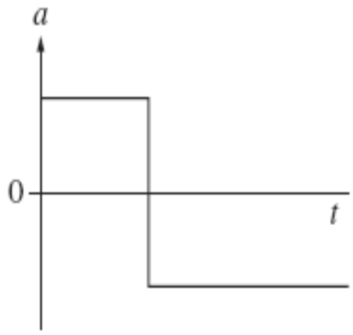
(International Baccalaureate Organisation, 2006)

Excerpt from the HSC, October 2006 examination paper, Section 1.

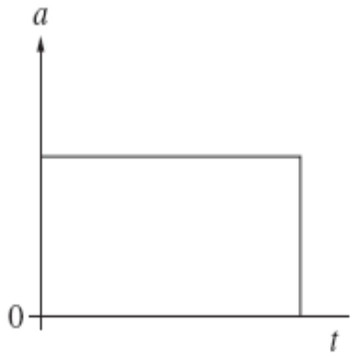
A stone is thrown horizontally from the top of a cliff and falls onto the beach below.

Which acceleration–time graph best describes the motion of the stone?

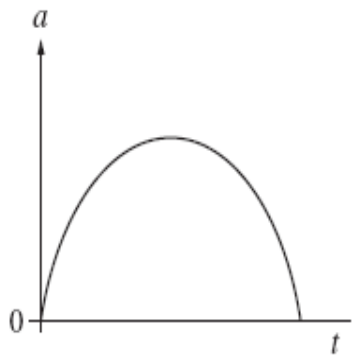
(A)



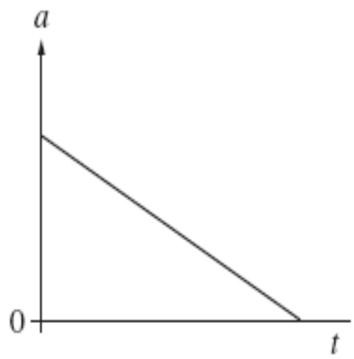
(B)



(C)



(D)



(Board of Studies, 2006)

EXTENDED RESPONSE QUESTIONS

Excerpt from the IBD, November 2006 Advanced Level Paper 2 examination.

(f) Calculate the escape speed for a spherical planet of radius 1.7×10^3 km having an acceleration of free fall at its surface of $1.6\,\mathrm{m\,s^{-2}}$. *[2]*

. . . .

. . . .

. . . .

(g) The mean kinetic energy E_K, in joule, of helium-4 atoms at thermodynamic temperature T is given by the expression

$$E_K = 2.1 \times 10^{-23}\,T.$$

Determine the surface temperature of the planet such that helium-4 atoms on the surface of the planet have the escape speed calculated in (f). *[2]*

. . . .

. . . .

. . . .

(h) Suggest **one** reason why, at temperatures below that calculated in (g), helium will escape from the planet. *[1]*

. . . .

. . . .

(International Baccalaureate Organisation, 2006)

Excerpt from the HSC, October 2006 examination paper, Section 1.

Question 17 (6 marks)

Parts of a space mission involve a spacecraft spending time in geostationary orbit, and then returning safely to Earth.

Analyse the forces acting on this spacecraft during these parts of the mission.

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(Board of Studies, 2006)