BIOLOGY TEACHING IN SECONDARY SCHOOLS IN SINGAPORE: THE HISTORICAL BACKGROUND, RECENT DEVELOPMENTS AND THE CURRENT PERSPECTIVES OF TEACHERS

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Graduate School of Education

2019
THESIS DECLARATION

I, Vanessa Neranjani D/O Muhundan, certify that:

This thesis has been substantially accomplished during enrolment in the degree.

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Ministry of Education, Singapore EDUN N32-07-005. Request No: RQ89-15(08)

This thesis does not contain work that I have published, nor work under review for publication.

Vanessa Neranjani D/O Muhundan

24th January 2019
ABSTRACT

The general purpose of this study is to develop an understanding of the evolution of secondary school biology teaching in secondary schools in Singapore. The first research question seeks to develop an understanding of the historical background to the education system in Singapore from the colonial times in 1920 to 1958 with special reference to the development of the teaching of science. The second research question seeks to develop an understanding of the teaching of science, from 1959 until recent times with special reference to the teaching of biology. The third research question seeks to develop an understanding of the issues, which are currently of concern to secondary school biology teachers and the perspectives they have regarding the teaching of biology in Singapore.

Document analysis of historical documents was used to address the first two research questions. Four semi-structured group interviews were conducted with three teachers each time for the purpose of the third research question. Data for this study were analysed using the general qualitative data analysis method described by Miles and Huberman. The findings of the first research question show the education-economy relationship that was essential to Singapore’s survival as an independent nation. Findings of the second research questions show the versatility of Singapore’s education system through its ability to support the economy with a skilled workforce. Findings of the third research question show the perspectives and concerns of secondary school biology teachers regarding the teaching of biology in Singapore. This includes the teachers’ perspectives and concerns on new initiatives and curriculum changes such as the inclusion of molecular biology in the biology curriculum.

The findings of the study provide implications for future development of policy and practice, as they may inform policymakers of the impact of their decisions on the biology teachers’ work and their professional development.
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CHAPTER ONE

INTRODUCTION

1. Introduction

Biology as a teaching subject in secondary schools in Singapore has a relatively short subject history compared with physics and chemistry. Recent advancements over the last two decades have led to an exponential increase in the content of biological knowledge (Tan, Lim & Poon, 2014). Biology was initially perceived by some scientists and educators as a subject with little relevance and significant only in preparation for a medical career. However, as described by Goh, Diong & Yeo (1989), the purpose of biology education is to prepare students for life and living as well as for an understanding of the environment. Biology is not only concentrated on the discovery of new information but the utilization of acquired knowledge for useful purposes of everyday life. The issues of today are increasingly bio-social in nature and biology teachers have an increasingly important role in preparing students for the future.

Whilst there has been some research conducted in relation to the teaching and learning of general sciences in the Singaporean context (Tan & Yates, 2007), research undertaken to understand the teaching of biology as a secondary school subject in Singapore remains neglected. This indicates a need to enhance our understanding of how the teaching of this subject has evolved in the Singaporean context and the issues teachers face in teaching it. The issues teachers face have a direct impact on how the subject is taught in the classroom, and consequently how the students learn the subject (Fordham, 2012).

In addition, Singapore students have performed consistently well in international comparative studies in the area of science (Tan, Lim & Poon, 2014). However, there have been few science education research publications in this context. The academic achievements of Singapore students have been an area of interest for many developing countries. Singapore is a country with little or no natural resources and yet, its economic success has surpassed many more well-equipped nations (Tan, Lim & Poon, 2014). Many researchers and government leaders have attributed this success to the versatility and strength of the education system.
Education has a key role in developing a workforce with the requisite knowledge, skills, attitudes, and values (Tan, 2012).

Therefore to address this deficit in knowledge base regarding the teaching of biology, this study focuses on developing an understanding of the evolution of secondary school biology teaching in secondary schools in Singapore through the following areas - the historical background of the education system in Singapore (1920 – 1958) with special reference to the development of the teaching of science; the recent developments to the teaching of science from 1959 to recent times with special reference to the teaching of biology; and lastly the perspectives of a sample of teachers regarding the teaching of biology today.

This introductory chapter firstly presents the research aims and research questions of the study; secondly, the significance of the study is outlined; following this, an overview of the research methods is provided; finally, the structure of the thesis is presented. The research methods are dealt with in a general way in this chapter, but they are discussed in greater depth in Chapter Four.

2. Research Aims and Research Questions

This study has three main aims and three research questions.

2a. First research aim and question

The study sought to develop an understanding of the historical background to the education system in Singapore from the colonial times in 1920 to 1958 with special reference to the development of the teaching of science. Much of the available literature on Singapore’s education system during the colonial times focuses more on the 20th century rather than the early 19th century. Therefore this part of the study is limited to educational developments in the teaching of science during the 20th century, in particular, the period from 1920 to 1958. The educational reforms brought about by foreign rulers during the colonial and World War Two period had a significant impact on the education system in Singapore and subsequently on the teaching of science in secondary schools. The educational reforms built the foundation for the
introduction of the teaching of biology and these reforms and impacts will be described in
Chapter Five. In line with this aim, the first research question is as follows -

*What is the historical background to the education system in Singapore from the colonial times (1920) until the pre-independence period (1958) with special reference to the development of the teaching of science in secondary schools?*

**2b. Second research aim and question**

The study sought to develop an understanding of the teaching of science, from 1959 until recent times with special reference to the teaching of biology. During this period, globalization and foreign influences had a strong impact on the development of the nation’s education system. It was noted that some form of simple biology was taught in the 1950s. Over the time period of the 1950s to 2000s, biology teaching moved from a marginal to a more central position in secondary education. The impact and the subsequent reforms and policies that were introduced will be described in Chapter Six. In line with this aim, the second research question is as follows -

*What are the recent developments of the education system pertaining to the teaching of science in secondary schools in Singapore from 1959 to recent times with special reference to the teaching of biology?*

**2c. Third research aim and question**

The study aims to develop an understanding of the issues which are currently of concern to secondary school biology teachers and the perspectives they have regarding the teaching of biology in Singapore. It aims to provide insights to inform considerations for policy and further research, specifically in the teaching of secondary school biology, and the preparation and training of secondary school biology teachers. This will be described in Chapter Seven. Data for this research question was collected using four semi-structured interviews at four randomly selected government secondary schools in Singapore. A total of twelve teachers were interviewed. The data were analysed using qualitative data analysis methods described by
Miles and Huberman (2014). The details of data collection and data analysis are described in Chapter Four. In line with this aim, the third research question is as follows –

What issues are currently of concern to secondary schools’ biology teachers and what perspectives do they have regarding the teaching of biology in Singapore secondary schools?

3. Significance of the study

Singapore is a small island with a relatively large population. One advantage Singapore has over her neighbours is her strategic location at the southern tip of the Malay Peninsula which has made Singapore a viable trading port. However, with little or no natural resource, there is a heavy reliance on human capital and ensuring that its people are skilled enough to create a robust workforce that will run and sustain its economy (Tan, Lim, Poon, 2014). Therefore, the education sector became a focal point in ensuring the economic success of the nation.

With the emergence of knowledge-driven economies, there is a need to re-assess the direction of the education system in Singapore (Gopinathan, 1985). The new economy is driven by science knowledge and skills, Information and Communications Technology, as well as complex ways of processing information (Hargreaves, 2003). This shift in the education landscape calls for a replacement of traditional teaching methods with more progressive pedagogical approaches such as collaborative learning and differentiated teaching (Tan, Chow & Goh, 2008). For Singapore to continue to survive and thrive in a volatile, uncertain, complex and ambiguous world, it is imperative that much investment is given to the nurturing and development of the workforce through a flexible and versatile education system.

Education in Singapore has, since the colonial period, acted as an instrument of its economic policies and nation-building (Blackburn, 2017). According to Gopinathan (1974), the educational policies adopted in Singapore reflect an education-economy relationship. The implementation of the educational policies aimed to build a skilled workforce in alignment with the demands of the economy. Through this education-economy relationship, Singapore was able to achieve a tight coiling of education and training systems with state-determined economic
policies (Gopinathan, Deng & Lee, 2013). This contributed to Singapore’s economic success despite its limited natural resources. During the period just before independence (1950 - 1964), the teaching of science received greater emphasis and was made more widely available. Biology, being a specialised subject within science, was only introduced after a significant foundation was developed in the area of science education after 1958. It was only after independence (1965), that the government of Singapore identified life sciences as one of the vehicles to drive the socio-economic success of the country.

This study, therefore, serves to illustrate the importance of this education-economy relationship through the study of the historical background and the recent developments of the education system and the manner in which the teaching of biology and science evolved in alignment with the changing economy.

4. Location of the researcher

In presenting this chapter, Roth’s (2005) insight of the events that have taken place in history is highlighted. These insights are framed in parallel with the researcher’s position as a biology student (from 1991 – 2002), biology teacher (from 2008) and a head of a level for lower secondary science (from 2011). As the researcher of this study is also a biology teacher at the secondary level, it was inevitable that a certain degree of experience and pre-conceived notions of biology teaching would be brought to this study. These influences were acknowledged to allow the analysis of the research data to be more open and transparent.
5. Research Methods

5a. Theoretical framework

This study is located in the *interpretivist paradigm*. The interpretivist paradigm directs the researcher in understanding the meaning of human and social actions (Schawandt, 2001). An important idea behind the interpretivist paradigm is that reality is socially constructed and therefore, what we understand is always negotiated within cultures, social settings, and relationships with other people. With the interpretivist approach, the researcher is the primary data-gathering instrument where carefully constructed questions aimed at understanding a phenomenon through semi-structured or open-ended interviews are often used. Another characteristic of the interpretivist approach is that it can generate a significant amount of data from a small number of participants which is relevant for this study. One way researchers can apply the interpretivist paradigm is through the use of the concept of perspectives. This was how the interpretivist paradigm informed the third research question which investigates the concerns and perspectives of secondary school biology teachers.

The theoretical position located within this broader research paradigm is *symbolic interactionism*. Symbolic interactionism, which stresses the way individuals see, define, interpret and react to a given situation (Woods, 1992), is consistent with this research position. Indeed, symbolic interactionism is a major theoretical position within the interpretivist paradigm. It is both a theory and an approach to the study of human behaviour (O’Donoghue, 2007). People construct meaning by interpreting their social interactions (Bogdan & Biklen, 2007) and communicate these meanings. An important idea behind symbolic interactionism is that human interactions and actions can only be understood through meaningful communication.

5b. Data collection

Document analysis was used to address the first two research questions. Historical documents and contemporary documents of a primary and secondary nature were studied and analysed for this study. The study of documents is consistent with the interpretivist approach to inquiry. Interpretivists often adopt a descriptive analysis of historical documents to establish an
understanding of the subject of research. The review of historical documents is one of the most effective methods of collecting data from the colonial period as historical events can no longer be observed.

To further deepen the data collected, an interview was also conducted with a Professor from the National Institute of Education. She is the Deputy Head (Teaching and Curriculum Matters) for the Natural Sciences and Science Education faculty at the National Institute of Education in Singapore. She was also previously a biology teacher at a secondary school in Singapore. Her position previously as a secondary school biology teacher as well as currently, a professor in the National Institute of Education, provided further data on the perspectives of teachers in response to research question three. The interview provided an additional perspective to this study and contextualised and provided significance to the educational policies described in this study, specifically the policies implemented after independence. The findings of this interview are presented in Chapter Seven.

For the purpose of research question three, four semi-structured group interviews were conducted with three teachers each time, thus a total of twelve teachers were interviewed. Semi-structured interviewing was chosen for three reasons; firstly, the participants are allowed to react and comment on the guiding questions (Major & Baden, 2013) without strict restrictions. This allowed the teachers to feel comfortable to share their perspectives; secondly, semi-structured interviews have proven to be optimal in providing people's perceptions, meanings, definitions of situations and constructions of reality (Punch, 2009); thirdly, this type of interview allows the interviewer to pre-determine the direction of the interview and elicit appropriate responses from the interviewee to ensure a valid set of data.

5c. Data analysis

Data were analysed using the general qualitative data analysis method described by Miles and Huberman. The Miles and Huberman method describes a concurrent three-step process: data reduction; data display; and drawing and verifying conclusions. Data reduction or data condensation refers to the process of selecting, focusing, simplifying and abstracting the
data without the loss of significant information (Punch, 2014). Data display involves analysing and organising the data in a presentable format. By displaying the data, the stages of analysis are shown. This allows the researcher to determine the areas required for further analysis. Drawing and verifying conclusions is the third part of the Miles and Huberman approach to data analysis. The process of drawing conclusions begins early in the coding process. Important phenomena and propositions related to these phenomena are generated upon the initial reviewing of the data. Once all the data is analysed, the conclusions are verified and become more grounded.

6. Structure of the thesis

This thesis comprises eight chapters. After this introductory chapter, Chapter Two provides a background and context to this study. This chapter forms the background against which the research findings presented in the subsequent chapters can be interpreted in a more contextualized manner.

Chapter Three reviews the main bodies of literature underpinning the study. The first part of this chapter reviews relevant literature on biology education in three aspects, firstly on the importance of biology education, secondly on the biology curriculum and lastly on the factors affecting the teaching of biology. The second part reports the propositions asserted by researchers on teachers’ perspectives on the implementation of the curriculum.

Chapter Four details the research methods employed in this study. Firstly, the theoretical framework and the theoretical perspective are discussed. Secondly, the sampling of documents, schools, and teachers is described. Thirdly the data collection methods are reported, followed by a discussion of the data analysis methods. Lastly, the ethical considerations of the study are described.

Chapter Five aims to develop an understanding of the historical background to the education system in Singapore from the colonial times (1920) until the pre-independence period (1958) with special reference to the development of the teaching of science in secondary schools. This is in response to the first research aim of this study. There were three significant
stages of government from 1920 to 1958. They are the colonial times from 1920 to 1942, the Japanese occupation from 1942 to 1945 and the pre-independence stage from 1946 to 1958. The educational reforms brought about by these three stages had a significant impact on the development of the education system in Singapore as well as on the direction the education system eventually adopted. This chapter describes each of the three stages with an overview of the historical, political and social climate in Singapore at that time.

Chapter Six addresses the second aim of the study, which is to develop an understanding of the recent developments to the teaching of science in secondary schools in Singapore from 1959 to recent times, with special reference to the teaching of biology. Singapore went through three different phases in its education landscape from 1959 to 2011. These three phases were, the survival-driven phase (1959 – 1978), the efficiency-driven phase (1979 – 1996) and the ability driven phase (1997 – 2011) and they are used to organise this chapter.

Chapter Seven addresses the third research aim of this study which is to investigate the concerns of secondary school biology teachers in Singapore government schools, with regard to the issues they are facing in their everyday working lives. This part of the study will investigate the issues, challenges, and concerns that secondary school biology teachers in Singapore face.

Chapter Eight concludes the thesis by providing an overview of the study, highlighting the importance of the understanding developed in guiding educational policy and practice as well as offering recommendations for improving practice and further research.
CHAPTER TWO

BACKGROUND AND CONTEXT

The purpose of this chapter is to provide an overview of the Singaporean education landscape, therefore setting the specific background against which the research findings presented in the subsequent chapters can be interpreted. This chapter focuses on three different aspects of Singapore’s education system. The first section focuses on the three historical stages of education in Singapore determined by three different ruling periods, namely the colonial period, the Japanese Occupation and the nation’s current stage of education under independence. Throughout each stage, political as well as economic pressures had notable impacts on the development of educational policies. The second section describes the current structure of the education system in Singapore. The third focuses on the impact of globalisation and foreign influences on the education system.

1. Historical stages of education

The description of the historical stages of education is dealt with in a brief and general way in this section, giving only outlines, but is discussed in greater depth in Chapter Five and Six. The first and second historical stage of education refers to the colonial period and the Japanese Occupation respectively which are discussed in more detail in Chapter Five. The third stage refers to the independence period which is discussed in more detail in Chapter Six.

Education in Singapore acts as an instrument of its economic policies and nation-building (Blackburn, 2017). Singapore’s education academics, such as Gopinathan (1974) and Blackburn (2017), have labelled this as the education–economy nexus or relationship. This is further explained in Chapter Five. As mentioned earlier, there were three stages of government in Singapore. Each stage of government saw a different interpretation of the education-economy relationship. The education-economy relationship during the colonial administration focused on an economy of trade. The introduction of vocational and technical education was observed during the Japanese occupation in response to a manufacturing economy. The independence
stage saw the industrialisation of the economy with the promotion of the teaching of science and biology.

1a. Colonial period

The education-economy relationship is an important aspect to the development of the education system in Singapore. Education under the colonial administration was an instrument of the state and was used to promote economic growth through trade (Blackburn, 2017). A decentralised education system developed during the colonial administration, with different types of schools implementing the different curriculum. There were the English language schools, and the vernacular schools, namely the Malay language schools, Tamil language schools, and Chinese language schools. Vernacular schools refer to schools where lessons were conducted in the native languages of the main resident communities, namely Malay, Chinese, and Tamil. The development of a uniform policy and system of procedures occurred only after the Second World War in the 1950s.

According to Wilson (1978), the absence of a unified policy of education led to a general sense of inequality of treatment amongst the races as well as a lack of opportunity in the areas of employment and education. This impacted the teaching of science. The implementation of the teaching of science was not consistent throughout Singapore and students were graduating from school with varying levels of competencies. The colonial rule on the educational developments in Singapore is described in more detail in Chapter Five.

1b. Japanese Occupation

During the Second World War, Singapore was occupied by the Japanese from 1942 to 1945. The Japanese adopted a different approach towards education as compared to the colonial administration. There was an increased emphasis on vocational and technical education and a focus on science and economics. During the Japanese occupation, the economy evolved from one based on entrepot trade to an economy that required more industrial workers to satisfy a manufacturing economy.
After the war, these workers provided the basis of a small skilled industrial workforce that supplied the growing manufacturing sector of Singapore’s economy (Blackburn, 2017). When the Japanese left Singapore in 1946, the residents of Singapore desired more freedom in legislation and policy implementation. The impact of the Japanese occupation on the education system in Singapore is described in detail in Chapter Five.

1c. Independence until recent times

After the Japanese left Singapore, the British returned for a short period. There was more localisation of policies to suit Singapore’s specific needs (Chen & Koay, 2001). There was also a surge in demand for equal educational opportunities in Singapore by the locals. Singapore attained independence in 1965 and this period saw an increased emphasis on teacher training, education and development as well as the introduction of key educational policies which contributed significantly to the changing educational landscape in Singapore (Chen & Koay, 2001). These reforms contributed to a differentiated education system which introduced curricula and examinations that catered to students of different learning abilities and learning needs.

As the economic landscape evolved into one more focused on manufacturing, the emphasis on the teaching of science and biology in Singapore secondary schools increased (Tan, Lim, Poon, 2014). Science and technology became increasingly important to Singapore to compete as a viable economic entity and break away from the dependency on entrepot trade (Gopinathan & Chong, 2008). This paved the way for more current educational reforms as described in Chapter Six.

2. Structure of education system

Singapore currently maintains a highly centralized education system (Tan, Gopinathan & Ho, 2001) in which the curriculum and the syllabus are determined by the Ministry of Education. The education structure in Singapore follows a three-part system - six years of primary school, four years of secondary school and two or three years of pre-university education. Students are therefore provided with at least ten years of basic and compulsory
education. All Singapore citizens at the age of seven will begin their education with a compulsory six-year education in primary school. This is followed by a four or five-year secondary course. Following the secondary school course, there is a variety of pathways as determined by the students’ choices and abilities (Ministry of Education, 2018).

At each stage of the education system, it is desired that the students develop a set of skills through their education in school. This is known as the Desired Outcomes of Education (Ministry of Education, 2015). The desired outcomes of education are attributes that educators aspire to for every Singaporean student to have by the completion of formal education. These outcomes establish a common purpose for educators, which drives the policies and programmes in schools. Figure 2.1 provides an overview of the structure in the Singapore education system while Table 2.1 outlines the key attributes related to the Desired Outcomes of Education.

Figure 2.1

An Overview of the education structure in Singapore

Source: Ministry of Education (2018)
Table 2.1

*The Desired Outcomes of Education in Singapore Schools*

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Post-Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be able to distinguish between right and wrong.</td>
<td>Have moral integrity.</td>
<td>Have moral courage to stand up for what is right.</td>
</tr>
<tr>
<td>Know their strengths and areas for growth.</td>
<td>Believe in their abilities and be able to adapt to change.</td>
<td>Be resilient in the face of adversity.</td>
</tr>
<tr>
<td>Be able to cooperate, share and care for others.</td>
<td>Be able to work in teams and show empathy for others.</td>
<td>Be able to collaborate across cultures and be socially responsible.</td>
</tr>
<tr>
<td>Have a lively curiosity about things.</td>
<td>Be creative and have an inquiring mind.</td>
<td>Be innovative and enterprising.</td>
</tr>
<tr>
<td>Be able to think for and express themselves.</td>
<td>Be able to appreciate diverse views and communicate effectively.</td>
<td>Be able to think critically and communicate persuasively.</td>
</tr>
<tr>
<td>Take pride in their work.</td>
<td>Take responsibility for own learning.</td>
<td>Be purposeful in pursuit of excellence.</td>
</tr>
<tr>
<td>Have healthy habits and an awareness of the arts.</td>
<td>Enjoy physical activities and appreciate the arts.</td>
<td>Pursue a healthy lifestyle and have an appreciation for aesthetics.</td>
</tr>
<tr>
<td>Know and love Singapore.</td>
<td>Believe in Singapore and understand what matters to Singapore.</td>
<td>Be proud to be Singaporeans and understand Singapore in relation to the world.</td>
</tr>
</tbody>
</table>

Source: Ministry of Education of Singapore (2015)

The remaining parts of this section describe the primary, secondary and pre-university education in Singapore in more detail.

2a. Primary education

Formal compulsory schooling in Singapore begins at age seven in primary schools. This means that a Singapore student will start Primary One at age seven. Government primary schools follow a national curriculum which emphasises broad-based holistic education (Tan, Lim & Poon, 2014). The overall aim of primary education in Singapore is to provide students with a good foundation in English, mother tongue language, science, and mathematics. Science education is only introduced in Primary Three when the student is nine years old.
At the end of the six-year primary education, all students will sit for the ‘Primary School Leaving Examination’ (Tan, Lim & Poon, 2014). This is a major national examination which determines students’ placement into secondary schools.

2b. Secondary education

There are three different types of secondary schools in Singapore - government schools, government-aided schools, and independent schools. Government schools are fully funded by the government whereas, government-aided schools are partially funded by the government. Independent or autonomous schools are not funded by the government. However, despite these differences, the three different types of schools follow the same curriculum and syllabus as prescribed by the Ministry of Education in Singapore (Tan & Ng, 2005).

Secondary education in Singapore is diverse in the combination of subjects offered as well as the number of niche programmes. General science is a mandatory part of the national curriculum up to Secondary level when the students are 14 years of age (Tan, Lim & Poon, 2014). At the upper secondary levels, biology and physics are offered as an elective in which it is offered as a single subject or an integrated subject option, Science (Chemistry with Biology or Physics with Biology). This is explained in more detail in Chapter Six.

Secondary education offers either a four or a five-year programme that concludes with the General Certificate of Education Ordinary Level examinations. There are two main courses of study in government secondary schools, namely Express and Normal. The students’ results from the Primary School Leaving Examinations will determine the placement of the students in one of the two courses. The Normal course is further divided into Normal (Academic) and Normal (Technical). Students in the Normal (Academic) course will study academic based subjects while those in the Normal (Technical) course follow a practice-oriented curriculum. All students in the Normal course sit for the General Certificate of Education Normal Level Examination at the end of four years of secondary education. Students in the Normal course who perform well during this examination will be awarded an opportunity to pursue the General Certificate of Education Ordinary Level Examination at the end of their fifth year. Students in
the express course will sit for the General Certificate of Education Ordinary Level Examination at the end of their fourth year and hence will complete their secondary education in four years.

Since 2004, some schools have offered a six-year integrated programme where students progress to pre-university education without sitting for the General Certificate of Education Ordinary Level Examination. Schools offering the integrated programme will optimise the time freed up from preparing for the national examinations to provide greater breadth in the academic and non-academic curriculum (Ministry of Education, 2017). There are currently 18 schools in Singapore offering the integrated programme.

There have been several different educational initiatives introduced by the Ministry of Education in the past two decades to drive the knowledge-driven economy of Singapore. The initiatives such as ‘Information Technologies Masterplan’ and ‘Teach Less, Learn More’ have had a significant impact on secondary school science teaching and will be described in Chapter Six. Teachers faced certain challenges in incorporating these new initiatives. These challenges and concerns are addressed in Chapter Seven.

2c. Post-Secondary education

As discussed, there are national examinations at the end of primary and secondary levels which determine the placement of students in the various educational institutions in Singapore. Post-secondary educational institutions are characterised by numerous pathways. One of the pre-university pathways involves enrolment in junior colleges in Singapore. At the end of the two-year course in junior colleges, the students will sit for the General Certificate of Education Advanced Level examinations. The junior college curriculum is regarded by government leaders as a successful system providing a robust and rigorous pre-university education (Teo, 2003).

There are also five polytechnics and two tertiary art institutions in Singapore which offer alternative post-secondary options for students. These options also serve as pre-university routes for the students. These institutions provide courses in more specific areas of study as compared to junior colleges.
3. Globalisation and international influence

In developing a holistic understanding of the teaching of biology in Singapore, it is important to understand the connection between the impacts of globalisation and the development of the curriculum. It is also important to understand the influence from foreign countries to describe the rationale behind certain educational reforms and policies made in Singapore.

3a. Globalisation

Globalisation is defined as the accelerated international flow of goods, capital, labour, services, and information. Education is responsible for preparing students to live in a world that is increasingly more complex due to the impact of globalisation (Carnoy and Rhoten, 2002) and educational change is important in ensuring citizens are able to cope and survive in the globalised world. Globalisation has contributed to economic, political and cultural transformations (Monkman & Baird, 2002) which have had an impact on education as well. Carnoy (1999) explains how globalisation has affected education in the following ways –

1. The need to increase the education level in the labour force and provide opportunities for adults to acquire new skills;
2. The need to increase spending on education to encourage a more educated labour force;
3. The need to increase emphasis on mathematics and science curricula;
4. The need to introduce Information Communications Technology (ICT) into education; and
5. The need to re-examine the schools’ roles as an expression of modern culture.

Education is responsible for preparing young people to work and live in a globalised nation; therefore the impact of globalisation on education should not be ignored (Carnoy & Rhoten, 2002). A knowledge-based economy has shifted the emphasis and the position of education and knowledge in society (Lee et al., 2008). There is a greater reliance on intellectual capabilities of an individual as well as the ability of the individual to apply knowledge acquired. The pressure on the education system to produce such high functioning individuals to drive this
knowledge-based economy is immense. Therefore, it was important that a shift in the educational approaches and policies be undertaken in Singapore after independence. Lee et al. (2008) further explains that due to the emergence of knowledge-based economies, the ability to accumulate knowledge is no longer sufficient. Students also need to be adept in processing data that is made available through the many channels of information technology into usable information.

Many countries have recognised a need to reshape and realign their educational policies in order to equip their citizens with the necessary knowledge and skills (Power, 2007). Singapore recognised this need for educational change and adapted with the introduction of initiatives, such as the ‘Thinking Schools, Learning Nation’. This policy was aimed specifically at dealing with the knowledge-based economy. The impact of this policy and details of other initiatives are described in Chapter Six.

In deciding and implementing these changes, Singapore looked towards countries with strong educational foundations such as the United Kingdom and Japan for inspiration. Singapore has had a long history of adopting and localising educational ideas and practices from other countries (Tan, Gopinathan & Ho, 2001) even during its early stages of development.

3b. International Influence

As mentioned, many countries saw the need to re-align educational policies to the emergence of knowledge-based economies and two of these countries have had a significant impact on Singapore’s education system. Singapore localised many foreign ideas to suit its own multi-racial society. Singapore’s survival depends on openness to global influences (Tan, Gopinathan & Ho, 2001) and it is important that Singapore adopted and adapted educational policies from other countries to remain competitive. Two countries, in particular, have had major influences in the past and present educational policies in Singapore, namely the United Kingdom and Japan. The areas of education in which these countries were a source of influence are illustrated in this section. The areas of influence from the United Kingdom is outlined first because the impact the United Kingdom had on Singapore’s education system was mainly
during the pre-independence period. The influence from Japan is illustrated next because Japan was an important source of influence during Singapore’s independence and currently.

**United Kingdom.**

The United Kingdom’s colonial rule left behind an educational legacy that was characterised by a segmented school system with deep resentment on the part of the non-English educated (Gopinathan, 1974). Even though Singapore became independent in 1965, Singapore’s Ministry of Education, in collaboration with the University of Cambridge Local Examinations Syndicate administers the General Certificate of Education (Normal, Ordinary and Advanced Level) - commonly known as the GCE N Level, GCE O Level and the GCE A Level in Singapore (Lee, 2014). The United Kingdom influenced Singapore’s education system in three main areas - the structure of the education system; assessment; and teacher training. The influence from the United Kingdom is dealt with in a general way in this chapter but is discussed in greater depth in Chapter Five.

As a colonial state before 1958, the education system in Singapore followed closely the education *structure* in the United Kingdom (Gopinathan, 1974). The structure of the education system and its path of progression for students are similar to the ones used in the United Kingdom. All children aged five to sixteen in the United Kingdom receive full-time education. Singapore adopted a similar educational structure in which students receive full-time education starting from the age of seven.

Students in the United Kingdom leave primary school at the age of eleven, moving on to secondary school. Parents can choose to educate their children at state or private schools. Students in Singapore also move on to secondary schools at the age of twelve. The similarity in the education structure in the United Kingdom and Singapore is representative of the historical influence the United Kingdom had on Singapore.

The United Kingdom had a strong influence on the academic *assessment* in Singapore. The present national examinations are the Cambridge based General Certificate of Education level papers. The syllabus and curriculum used in Singapore therefore, are determined by
parameters and specific objectives from Cambridge. As mentioned by the then Minister of Education, Tharman Shanmugaratnam (Ministry of Education, 2004), the exams in Singapore serve a key purpose in education and anchor Singapore’s meritocratic system.

Instructional strategy is often dominated by assessment criteria (Goh, Diong & Yeo, 1989). Therefore in a society that prioritises meritocracy, the teaching strategies in Singapore schools are influenced by examination. This has contributed to teaching for examination results. However as described by Kim, Tan & Talaue (2011), to solve problems in the present and future society, it is more important for students to seek knowledge creatively rather than merely recapitulating knowledge obtained. Recognising this, the science curriculum in Singapore emphasised science as inquiry. This is explained in Chapter Six.

In 1946, the British colonial government developed a Ten-Year education plan for Singapore. The details of this plan are described in Chapter Five. However, to illustrate the influence of the United Kingdom on teacher training in Singapore, certain aspects of the plan will be highlighted in this section.

The first stage in the Ten-Year plan entailed the establishment of a training college for teachers in the colony (Doraisamy et al., 1969). Established on 1st March 1950, the Teacher Training College (TTC) was Singapore’s first permanent, full-time training college for English-medium school teachers. The college’s first principal was J. D. Joseph, a senior education officer.

Lecturers who were involved with the beginnings of the Teachers’ Training College, were trained and educated in the United Kingdom (Wilson, 1978). However, there was a suitable and reasonable amount of localization infused into the teaching curriculum to ensure the program was pitched at a level appropriate for beginning teachers in Singapore.

In 1960 the Teachers’ Training College included the training of university graduates as secondary school teachers and the training was made compulsory for all new non-graduate and untrained teachers who had taken up teaching in Singapore on or after 1 January 1959 (Wong & Gwee, 1972). This signified a concerted effort by the government to increase the competency of
the teachers. Eventually, the college developed into the Institute of Education in 1973. Teacher training is further described in Chapter Six.

**Japan.**

The Japanese education system was a strong influence in the development of Singapore’s education system, particularly in the area of science. As mentioned by the then Minister of Education, Tharman Shanmugaratnam during the Ministry’s Work Plan Seminar (Shanmugaratnam, 2005), Japan’s changes in education were significant and influential to Singapore. The Japanese implemented changes in education that contributed to the reduction of the curriculum which allowed for the introduction of newly integrated learning subjects in all schools. This was done to promote a thinking culture in schools in Japan. In 2002, Japan introduced The Model for Japanese Education in the Perspective of the 21st century to address the inadequacies in the education system. According to Green (2000), the Ministry of Education in Japan recognised that the Japanese economy had to move rapidly towards the high-technology and high value-added areas of production and services. Therefore the education system evolved according to the changing economic landscape. This was very similar to the perspective adopted by the Ministry of Education in Singapore in which the country’s education sector moved in tandem with the economy. The new initiatives showed a shift in the education system of Japan. There were more opportunities for critical and analytical thinking (Motani, 2005) rather than simply memorising content. The recent shift in Japan’s education system was similar to the paradigm shift in Singapore in current times.

Japan’s lesson study practice was another notable initiative adopted by Singapore. Lesson study is a professional development platform which allows teachers to share their views and teaching practices with their colleagues (Fernandez & Yoshida, 2004). This platform serves not only to improve the teaching and learning in the classroom but also the professional discourse between teachers (Chen & Koay, 2001). Singapore has adopted and adapted the lesson study concept into Professional Learning Teams, which serve as a platform for the professional development of teachers.
In addition, Japan has a strong science educational system. Japan attributes its highly industrialised and innovative society to its beginnings of science education (Kawasaki, 1996). The role that the teaching of science played in Japan’s economy influenced the perspective Singapore government adopted in industrialising its own economy through education. The teaching of science was prioritised and received more emphasis during Singapore’s independence.

This chapter has provided the background and context to the study. To ensure the nation’s economic success in a globalised environment, Singapore’s education structure was reformed to meet the demands of a globalised nation. To appreciate the educational reforms adopted by Singapore and its impact on the teaching of science and biology, it is important to review literature centrally relevant to biology education and teacher’s perspectives on implementing the curriculum. This is addressed in Chapter Three.
CHAPTER THREE
LITERATURE REVIEW

1. Introduction

The discipline of biology is growing at an unprecedented rate, as more is understood of life at every level. Such developments in knowledge about biology place great demands on teachers due to the increasing content (Kampourakis, 2018). Therefore it is necessary to conduct a review of literature on the teaching of biology. This chapter is divided into two parts. The first part of this chapter reviews relevant literature on the teaching of biology in two aspects, firstly on the objectives of the teaching of biology and secondly on the factors affecting the teaching of biology. The second part reports on the importance of teachers’ perspectives and the challenges faced by teachers in implementing the biology curriculum. These two bodies of literature together aim to provide the necessary contextualization of this study.

2. Teaching of biology

The Journal of Biological Education is established as the authoritative voice in the world of biological education. This journal aims to bridge the gap between research and practice, providing information, ideas and opinion, in addition to critical examinations of advances in biology research and teaching. This journal is used to provide a sound background on the teaching of biology.

2a. Objectives of teaching biology

Recent advancements over the last two decades have led to an exponential increase in the content of biological knowledge, understanding of life and application to industry (Tan, 2015). The objectives of the teaching of biology have therefore changed as biological knowledge increased. The objective of the teaching of biology was initially perceived by some scientists and educators, as a subject with little relevance and significant only in preparation for a medical career. However, biological research in the twenty-first century has had an impact on various aspects of human life, with important implications on how we understand health,
disease, and identity (Kampourakis, 2018). This has led to an adjustment of the objectives of the teaching of biology.

To Lederman, Lederman & Antink (2013), the objective of teaching biology is to create a scientifically literate society. The expectation is for an individual to understand the subject matter, nature of scientific knowledge, and nature of scientific inquiry. According to him, making informed decisions about scientifically based issues requires that one understands the limits of knowledge and how it was developed. Scientific literacy has always been at least partially associated with an individual’s ability to make informed decisions about scientific issues.

According to Kampourakis (2018), many policy documents in various countries all over the world often suggest that scientific literacy should be the main objective of science education in schools. He adds that scientific literacy is especially important for biology, as there are many socio-scientific questions that students will encounter during their lives which may demand relevant decisions that require a good understanding of biology. Therefore, literacy in biology is a core component of scientific literacy.

There are numerous perspectives on scientific literacy and what constitutes it. However in the area of biology, the main aspects of scientific literacy involve the following: firstly, the study and awareness of the human body and life forms (Goh, Diong & Yeo, 1989); secondly, the understanding of the relationship of living things with the environment (Rowland, 2007); and lastly, the awareness of the environmental changes which are important to our society and our generation.

The first objective focuses on the study of living organisms, divided into many specialized fields that cover their morphology, physiology, anatomy, behavior, origin, and distribution (Koba & Tweed, 2009). Biological knowledge yields health and economic benefits and it is a science that encompasses many aspects of life on Earth (Rowland, 2007). As mentioned by Tan (2015), biology is one of the most dynamic research disciplines within the natural sciences and new research discoveries are published almost daily as research articles in
scientific journals. According to Brill, Falk, and Yarden (2003), the gap between the accumulated knowledge in biology, and the knowledge that is taught in schools will increase as the research discoveries increases. They proposed a journal club in which teachers can stay abreast with the research discoveries in the biology field, therefore ensuring incorporation of these discoveries into everyday teaching.

The second objective focuses on the relationship of living things with the environment. To Nurse (2016), the ability of students to understand the world in which they live depends on their understanding of biology. DeBoer (2004) agrees that biology education provides students with a broad intellectual understanding of the natural world, and trains students to think scientifically and to utilize science concepts for effective living.

The third objective focuses on environmental changes. The issues of today are increasingly biosocial in nature and biology teachers have an increasingly important role in preparing students for the future (Goh, Diong & Yeo, 1989). This knowledge can empower the students to create ideas and perhaps necessary innovative solutions to the current environmental problems. The skills developed by studying biology are ones that innovators, problem solvers and leaders of tomorrow will need (Nurse, 2016).

2b. Factors affecting the teaching of biology

Teaching and learning of biology exist in a complex ecology of multiple aspects, however, upon the review of the literature on the factors affecting the teaching of biology, four factors were identified according to relevance to this study and are described below. These factors were namely, content, pedagogy, pre-conception, and assessment.

Biology content is not inert (Ning & Zheng, 2018). In fact, it is ever changing and aids in our understanding and explanation of the world and life around us. Biology is a dynamic science (Karthigeyan, 2014) and is currently one of the most progressive subjects with respect to recent scientific discoveries. Such developments in human knowledge about biology place great demands on teachers who, when they were at school, may have been taught certain things that are now regarded as misleading or even wrong (Kampourakis, 2018).
The recent discoveries on DNA (Deoxyribonucleic Acid) and its function have changed the biology content in secondary schools. Gericke and El-Hani (2018) discuss the teaching and learning of genetics and its importance as a topic in secondary school biology in their article on *Genetics* in Kampourakis (2018) book on *Teaching Biology in Schools*. They explain that genetics is a cornerstone of any biology course because, without genetics, it is impossible to explain the hereditary aspects of life. In addition, comparative studies conducted by Bahar et al. (1999) and Gericke & Smith (2014) have shown that genetics is perceived as one of the most difficult topics to teach and learn in biology. According to Tsui & Treagust (2013), these difficulties are both conceptual and linguistic in nature. Mdolo & Mundalamo (2015) explain examples of the linguistic challenges faced by teachers and students in genetics which include confusion of terms commonly used in the topic that sound alike such as *homozygous* and *heterozygous*. At the conceptual level, the invisibility and inaccessibility of genetics concepts make the subject complex and abstract (Knippels, 2002; Marbach-Ad & Stavy, 2000) and therefore difficult to understand.

Recently, it has been argued that the biology curriculum should shift even more from focusing on single gene disorders to polygenetic disorders (Dougherty, 2009). The current focus on secondary biology content is on monogenetic heredity, common in classical Mendelian genetics. Dougherty (2009) feels that this does not prepare students for effective participation as medical consumers.

In most countries, the introduction of genetics is delayed until the upper secondary levels, when the student is 15 years or older. Unfortunately, as noted by Venville, Gribble & Donovan (2005), by this time, most students have developed some ideas of genetics from unreliable sources such as movies, comic books, television drama, and science fiction. These ideas often lead to pre-conceptions that are scientifically inaccurate. This is further dealt with later in this section.

*Pedagogy* is essential in ensuring that the knowledge, skills, and understanding of how science works are suitably integrated (Liversidge et al., 2009). The need for innovation of
educational tools and strategies is particularly evident in the science field where classic teaching methods have proved inadequate (Santucci et al., 2003). There is a large amount of content in teaching biology and there is a limited time to cover the content fully (Koba & Tweed, 2009). Despite the limitations, teachers need to formulate a suitable pedagogy that would ensure students can make sense of what they learn (Marzano, Pickering, & Pollock, 2001).

According to Magnusson, Krajcik & Borko (1999), pedagogical content knowledge is fundamental for the effective teaching of science. Shulman (1986) introduced pedagogical content knowledge as the subject matter knowledge for teaching that includes an understanding of what makes the learning of specific topics easy or difficult. After a summit on pedagogical content knowledge in Colorado (Mdolo & Mundalamo, 2015), it was further iterated that strong pedagogical content knowledge is important for effective teaching of a particular biology topic and not just possession of a Bachelor’s degree in that particular subject (Liversidge et al., 2009).

There are two similar interpretations of pedagogical content knowledge. According to Geddis & Wood (1997) and Shulman (1986), pedagogical content knowledge is informed by knowledge of subject matter, general pedagogical knowledge, knowledge of students’ characteristics and knowledge of context, which includes curricular materials and the learning environment. For Mavhunga and Rollnick (2017), pedagogical content knowledge has five components, namely knowledge of: students’ prior ideas, including misconceptions; curricular saliency; what makes the topic easy or difficult to understand; appropriate representations including analogies; and conceptual teaching strategies. Curricular saliency includes knowledge of the purpose of teaching the topic, depth of coverage as well as knowledge of what should be taught or left out (Geddis & Wood, 1997). Both interpretations provide a comprehensive basis for a structured approach to a sound pedagogy towards the teaching of biology.

It has been shown by Randler and Bogner (2009), that teaching approaches in ecology, which is a topic in teaching biology, typically follow simplistic linear conceptions of ecosystems that mask the underlying complexity. But, as they discovered, the students end up learning simplifications that are not adequately representative of natural systems. As teachers,
we are in a constant battle to resolve the dilemma between the simplicity of teaching and the complexity of the content. According to Wheelahan (2007), in an effort to simplify the content, the content is presented to students as a one-dimensional knowledge structure which effectively denies students access to understanding. Therefore it is essential that the pedagogy used accurately reflects the intention of the curriculum. In the event it does not, students’ understanding is compromised.

Singapore recognised this need for a pedagogical change. Lee (2005) further explains that due to the emergence of knowledge-based economies, the ability to accumulate knowledge is no longer sufficient. As described later in Chapter Six, there was an introduction of several visions and policies, such as the Thinking Schools, Learning Nation, that was aimed specifically at dealing with the knowledge-based economy. The inquiry approach was also adopted as an instrumental tool in pedagogical approaches for the teaching of science and biology.

As mentioned earlier, students’ preconceptions play an important role in the accurate delivery of content. Before students receive formal education in schools, they are forced to make sense of everyday phenomena that sometimes intrigue and confuse them. Conceptions are developed, not only from previous experience but also from explanations from unreliable or unscientific sources (Koba & Tweed, 2009). These conceptions may also develop through the student’s individual experience and exposure to society and culture.

For example, students are unclear about the process of genetics and can, therefore, attribute a child’s dark complexion to his/her parent’s exposure to sunlight (Donovan & Bransford, 2005). In addition, students’ prior knowledge, which comes from their observations, perceptions, culture, language, prior teachers’ explanations as well as prior instructional materials (Cakir, 2008), acts as an obstacle to their conceptual understanding of genetics. In some cases, students’ traditional beliefs (Kibuka-Sebitosi, 2007) and personal experiences are major contributors to their misconceptions. There is often a failure to distinguish between cultural inheritance and genetic inheritance (Venville et al., 2005).
In order for a student to understand biology fully, it is essential that any misaligned previous conception be re-addressed to ensure that the student understands the scientific basis behind the phenomenon (Koba & Tweed, 2009). As highlighted by Korfiatis & Tunnicliffe (2012), teachers should find out what the students already know and create strategies that use the students’ knowledge to develop concepts in line with scientific knowledge. The teaching of science, therefore, has to adopt a pedagogy that effectively dispels any misconceptions.

The easiest and perhaps the most assured way of changing a student’s previous conception is by allowing the student to experience the phenomenon from a scientific perspective. If the student goes through an experience that provides enough stimulation to provoke the pre-conception, then the scientifically sound concept will stand true in the student’s mind. This is one way in which the inquiry approach aids in ensuring the effective teaching of biology. The approach allows the students to experience biology rather than simply learning about it. Therefore, it is essential that an appropriate pedagogical tool is adopted for the teaching of biology.

*Assessment* is part of school experience and is integral to teaching and learning. According to Tan (2015), assessment refers to any procedures in which information about students’ learning are collected to facilitate decision making. Assessment can be termed formative or summative depending on the purposes of the assessment. Summative assessment refers to assessment used for the purpose of review of content, whereas formative assessment is closely associated with curriculum and pedagogy and is said to be central to good teaching practices (Nitko & Brookhart, 2014). In Singapore, assessment practices have generally been summative in nature and the idea of formative assessment is relatively new for most teachers (Tan, 2015). The challenges they face in implementing formative assessment is outlined in Chapter Seven.

Biological content is ever changing and the content aids in our understanding and explanation of the world and life around us. Therefore, it is essential that our mode of assessment, as well as our criteria for assessment, is as fluid as the changing content. According
to Anderson (1997), retention of knowledge is dependent on the usage of knowledge in everyday life. For example, skills like reading and writing are skills that will be retained for years to come because of the practicality of the skill. Biology concepts, on the other hand, are not practiced on an everyday basis and are therefore easily forgotten. The appropriate assessment tools would, therefore, become the key factor in ensuring the retention of knowledge.

There has been a significant reform in the assessment structure in science and biology education as highlighted in a study conducted in Hong Kong (Cheng & Cheung, 2005). This reform, observed in Singapore as well, reflects a shift towards more formative style assessment such as an assessment of alternative forms of students’ work such as performance, outdoor learning tasks, and debates. Currently, in Singapore schools, teachers are moving towards inquiry-based questions. This approach in assessment ensures that students develop answers based on the phenomenon observed. There is an increased amount of reasoning involved and this ensures the biology content is thoroughly analysed before the answer is given (Donovan & Bransford, 2005).

Through the study conducted in Hong Kong, it was noted that there was a need to help teachers change their views about science learning and teaching and appreciate the use of alternative forms of assessment strategies to reflect student performance. It is important, particularly to biology, that a formative style of assessment is adopted. Learning science can then be seen as a process of construction and reconstruction of science concepts in students’ minds (Cheng & Cheung, 2005).

Mirroring international trends in science and biology education reforms, the policymakers in Singapore are also examining ways to infuse formative assessment into the curriculum to improve and support students’ learning of science and biology (Tan, 2015). One of the key contributing factors to successful science teaching is an alignment of the inquiry process to assessment practices. This is a proposition that arose from the findings of the interview conducted for the purpose of this study and will be discussed in Chapter Eight.
2c. Biology education in Singapore

This section provides an overview of the beginnings of biology education in Singapore. Details are provided in appropriate sections later in this thesis.

Biology as a teaching subject in Singapore has a relatively short subject history compared with physics and chemistry. Recent advancements over the last two decades have led to an exponential increase in the content of biological knowledge, understanding of life and application to industry (Tan, 2018). Biology was initially perceived by some scientists and educators as a subject with little relevance and significant only in preparation for a medical career. However, as described by Goh, Diong & Yeo (1989), the purpose of biology education is to prepare students for life and living as well as for an understanding of the environment. Biology is seen as a subject that promotes an understanding of life and the relationship of living things as well as advocating an appreciation of man and his environment. Biology is not only concentrated on the discovery of new information but the utilization of acquired knowledge for useful purposes in everyday life. The issues of today are increasingly bio-social in nature and biology teachers have an increasingly important role in preparing students for the future.

Science was first officially introduced to Singapore schools in 1937 (Tan, 2018). It was noted that some form of simple biology was taught in the 1950s. However, there was no clear evidence of explicit biology classes conducted during this time. Over the time period of the 1950s to 2000s, biology education moved from non-existent to a more central position in secondary education. A review of the biology curriculum from the 1950s to 2000s reveals three major changes in the biology education in secondary schools through the years.

The first change in the teaching of biology was observed in the 1960s. The teaching of biology in the 1950s consisted mainly of a study of life from a descriptive approach and emphasis was placed on the acquisition of facts and the information that biologists had obtained. In the 1960s, teaching biology shifted to experimentation and discovery approaches. The second change was observed in the 1990s when the teaching of biology focused on life processes. The emphasis was on the relationships of man with the environment and other
organisms. The third change happened in the 2000s. Life sciences were incorporated into the syllabus with an emphasis on molecular biology. More emphasis was placed on the concept of genetics and Deoxyribonucleic Acid (DNA). This was in alignment with life sciences recognised as a socio-economic vehicle for Singapore.

A change in examination format was also observed during this time period. In the 1950s, only essay questions were set, however, during the 1970s, the questions focused more on explanation and less on description. Currently, more data-based questions are introduced in which students are expected to analyse the data provided and establish links between their content knowledge and the data provided. This was in alignment with the drive towards a thinking nation as will be described in Chapter Six.

Instructional strategy in the classroom is often determined by the assessment criteria. Therefore, as the assessment structure changed, the teaching of biology adapted accordingly. The teaching of biology was focused on the preparation of students for the examination. However, this approach was seen to defeat the purpose of the curriculum. Therefore in 2004, the Teach Less, Learn More initiative was introduced to promote more engaged learning, high-quality teaching, and innovative and effective instructional approaches.

3. Teachers’ perspectives

Globalization impacts teacher education (Gopinathan & Chong, 2008), and teachers are the first line of academic influence for future generations. The curriculum changes in Singapore are in response to the changing economic landscape. Singapore’s education system is therefore seen as one that is versatile and adaptable to change. As the curriculum changes, teachers are forced to adopt these changes and assimilate them into the current teaching framework. Teachers’ perspectives are important in ensuring the curriculum is implemented as intended. The recent scientific developments have had an important impact on the teachers’ perspectives, which is addressed in this section. The review of the relevant literature on the importance of teachers’ perspectives in implementing curriculum is described first. This is followed by the review of the literature on the challenges teachers face when implementing curriculum changes.
3a. Importance of teachers’ perspectives in implementing curriculum

There is a lot of research on how the values and perspectives of teachers influence their own approaches in curriculum implementation. The University of Stirling conducted a research on the curriculum making process in upper secondary schools in Scotland (Edwards, 2009) and the research showed that there are several factors affecting the way curriculum is prescribed. The role of teachers was highlighted as one of the main factors. Teachers’ preferred approaches to teaching and interacting with students may affect the intended curriculum implementation (Edwards, 2009).

Another study conducted in the United States of America investigated the approach of curriculum making through the initiation of curriculum projects in schools (Clayton, 2007). During the curriculum making process, beginning teachers reflected on their relationship with the curriculum, specifically their subject knowledge and their sense of curriculum ownership. These factors heavily influenced the manner in which the curriculum was implemented. The issues with the teachers implementing a particular curriculum approach on their own, without much guidance, is that the intended outcome of the approach may not be realised in its entirety (Tan, Lim, Poon, 2014).

The way a particular curriculum change is implemented will vary greatly from teacher to teacher and may be quite different from the expectation of the reformers (Jennings, 1996). There is a difference between the intended curriculum, which is decided by policymakers, and the enacted curriculum, which is the actual outcome in the classroom. Therefore, it is essential that there is coherence in practice as described by Cohen and Ball (1990). Coherence in practice depends more on how teachers understand, interpret, and internalize the reform messages for their own practice than on the alignment of those messages at the policy level.

The implementation of the curriculum depends very much on the meanings teachers give to the curriculum or the curriculum changes. These meanings determine the manner in which the curriculum is implemented. The constructed meanings on the curriculum are further translated into teachers’ classroom practices which in turn shape the implementation process.
(Rigano & Ritchie, 2003). Three meanings that teachers often associate with the curriculum were highlighted in the literature reviewed. They were, ownership, integrity, as well as the quality of the curriculum and each of these meanings, will be described in the next section.

Teachers’ curriculum ownership is increasingly gaining attention in many countries (Mikser, et al., 2016). Enhancing teachers’ curriculum ownership is a growing concern in many countries (Ballet & Kelchtermans, 2008). Although defined differently by different researchers, curriculum ownership is often regarded as a particular psychological stance of teachers (Pierce, Kostova & Dirk, 2003). This means that curriculum ownership refers to the extent and the manner in which teachers regard the curriculum as their own.

According to researchers who have discussed the notion of teachers’ curriculum ownership, the fundamental characteristic of this concept is that teachers feel entitled to make decisions regarding how curricular problems should be solved (Ballet & Kelchtermans, 2008). Therefore, teachers having ownership over curriculum means not only teachers being curriculum implementers but also curriculum developers (Mikser, et al., 2016). A study was conducted in Estonia on upper secondary school teachers and their views on the impact that teacher engagement in state-based curriculum making has had on their curriculum ownership (Mikser, et al., 2016). Through this study, it was ascertained that educational reforms in the area of the curriculum will have a greater chance of succeeding if the teachers were more involved with the curriculum making process. Through their involvement, ownership is derived, which ultimately leads to the accurate implementation of the curriculum (Mikser, et al., 2016).

As mentioned above, there is a gap between the intended curriculum and the enacted curriculum (Brown & Campione, 1994). There are many factors that affect the manner in which the curriculum is enacted. This part of the chapter focuses on the impact a teacher’s integrity has on the curriculum implementation.

Integrity focuses on the extent to which teachers’ enactment of materials in classrooms align with the intentions and plans of curriculum designers (Brown & Campione, 1994). As teachers, there is a strong sense of integrity in ensuring the curriculum is enacted as intended.
The integrity of implementation refers to the degree to which teachers’ adaptations of materials are congruent with the curricular goals and principles undergirding the structures of the curriculum (Penuel, Philips & Harris, 2014). Researchers who study the integrity of implementation focus on the degree to which teachers adhere to guidance embedded in curriculum materials as well as the integrity maintained in the delivery of the curriculum. Curriculum designers have a stake in curriculum enactment, but they have little or no control over the implementation process.

Therefore, teachers’ integrity is extremely important in ensuring the curriculum is implemented as intended. However, teachers are faced with challenges that may impede their desire to implement the curriculum completely as intended. These challenges are highlighted in the next section and in Chapter Seven.

The quality of the curriculum in this aspect refers to the ability of the curriculum to improve the quality of teaching and learning (Churchill & Williamson, 2004). Teachers endorse changes or initiatives only when they are convinced that the intended changes in education can improve the quality of teaching and learning (Churchill & Williamson, 2004). When teachers do not see educational initiatives benefitting students’ learning, they are likely to abort the implementation of the intended initiatives. Teachers, as Fullan (2007) describes, need support to understand and to believe in the value of the educational initiatives they are asked to implement. Teachers are often overwhelmed with administrative work which exhausts teachers’ energy and limits opportunities to reflect on the significance of the intended educational initiatives (Fullan, 2007).

The correlation between the perceived significance of educational initiatives and the intention to implement these initiatives can be attributed to the teachers’ commitments towards students’ academic learning as well as students’ personal development which transcend above all other aspects of school work (Nolan & Meister, 2000). The failure to improve the academic results of students despite implementing innovative teaching practices may lead to teachers
experiencing incoherence in the translation of policies to practices (Hairon, 2003). This may contribute to the teachers aborting certain initiatives that may seem ineffective.

3b. Challenges faced by teachers

The implementation of curriculum changes involve teachers using new teaching materials, adopting new teaching approaches and embracing new beliefs in teaching and learning (Fullan, 2007) which undoubtedly challenge their teaching skills. Some of the more relevant challenges to this study are highlighted and can be divided into three categories: re-learning of content; student engagement and attitudes; and limited resources. These challenges are dealt with in a brief manner in this chapter; however, these challenges were also highlighted by teachers interviewed for the purpose of this study and their perspectives are described in detail in Chapter Seven.

With curriculum changes, teachers are expected to 
*re-learn new professional content.* This professional content may be knowledge content as well as pedagogical content. An improvement or re-learning is required not only for the content knowledge of the teachers but also pedagogical knowledge to suit the implementation of new content and adoption of curriculum changes (Tan, 2018).

Teachers’ knowledge adequacy is an important aspect for the successful implementation of the intended curriculum. A sound grasp of the content knowledge is essential in ensuring the development of students’ correct conceptual understanding of the subject. As mentioned earlier, recent scientific discoveries have altered the biology curriculum with the introduction of molecular biology and it is important that the teachers have a sound grasp of this new content. Professional development courses are introduced to deal with the bridging of professional content (Tan, 2018). However, due to the time factor and responsibility towards their students, these courses often suffer from low attendance.

As mentioned earlier, teachers who do not possess sufficient pedagogical content knowledge tend to resort to repetitive teaching with an avoidance of answering questions from students (Loughran, Mulhall & Berry, 2008). Student centred activities would not be implemented or carried out due
to the teachers’ fear of implementing and facilitating these sessions. The facilitation process requires a sound knowledge of both pedagogical and content in nature. Therefore, teachers need to acquire or construct new professional knowledge in both content and pedagogy when implementing curriculum initiatives or changes (Niess, 2005; Windschitl, 2002).

*Student engagement* is essential for learning to take place. To teach is basically to engage students in learning. Student engagement is a multi-faceted construct that includes behavioral, emotional and cognitive engagement (Fredricks, Blumenfeld & Paris, 2004). To engage students in their learning, it is also important for teachers to take into consideration students’ approaches and orientations towards knowledge acquisition (Felder & Brent, 2005).

In other words, there are certain expectations of the students in the classroom. They are expected to behave in a positive manner, adhering to classroom norms with minimal disruption. However, this may not be the case in all classrooms in Singapore. There are classrooms with disruptive students and engaging them becomes a difficult task for the teacher.

*Limited resource and time* are one of the challenges teachers face. Teachers refer to textbooks for planning and teaching (Rigano & Ritchie, 2003) as well as to gain professional knowledge (Kesidou & Roseman, 2002). In the current reform climate, teachers have little time and less guidance to re-learn or re-think how learning takes place or how their instruction can be modified to take student’s needs into consideration (Marble, et al., 2000). Many teachers make instructional decisions based simply on their immediate needs to comply, survive, conform or meet a time constraint (Hargreaves, 2003). Situating the work of teaching in the wider social context, teachers are being asked to do more, but with less time and support to learn how to meet the new demands (Hargreaves, 2003).

The issue of insufficient time for lesson planning and classroom teaching has been widely articulated in empirical studies investigating curriculum implementation (Rigano & Ritchie, 2003). Insufficient time is often cited as the reason behind teachers refraining from implementing curriculum changes. The quality of the learning process is highly dependent on the pedagogy adopted by the teachers. However, with insufficient time and resources, teachers
are likely to resort to the traditional didactic teaching at the expense of using student-centred learning which is more time consuming (Windschitl, 2002). In this manner, the quality of science teaching is compromised.

This chapter has reviewed literature that is most centrally relevant to the research questions. The first part of the chapter reviewed the literature on biology education and the second part reported on the propositions asserted by researchers on teachers’ perspectives on the implementation of the curriculum. These two bodies of literature together aimed to provide the necessary contextualization to this study.

The next chapter describes the research methods used in this study. The theoretical framework and the data collection and analysis methods will be described.
CHAPTER FOUR
RESEARCH METHODS

1. Introduction

This study has three aims. The first aim sought to develop an understanding of the historical background to the development of Singapore's education system from 1920 to 1958 with special reference to the teaching of science. The second aim sought to develop an understanding of the recent developments of the education system pertaining to the teaching of science in Singapore from 1959 to recent times, with special reference to the teaching of biology. The third aim is to investigate the issues which are currently of concern to secondary school biology teachers and their perspectives regarding the teaching of biology in secondary schools in Singapore.

This chapter describes the research methods used in this study. It has five sections. Firstly, the theoretical framework and the theoretical perspective are discussed. Secondly, the sampling of documents, schools, and teachers is described. Thirdly the data collection methods are reported, followed by a discussion of the data analysis methods. Lastly, the ethical considerations of the study are described.

2. Theoretical framework

This study is located in the interpretivist paradigm. The interpretivist paradigm directs the researcher in understanding the meaning of human and social actions (Schawandt, 2001). The theoretical position located within this broader research paradigm is symbolic interactionism. Symbolic interactionism, which stresses the way individuals see, define, interpret and react to a given situation (Woods, 1992) is consistent with this research position. The manner in which this theoretical framework underpins this study is described in the next section.
2a. The interpretivist paradigm

A researcher adopting an interpretivist approach is interested in finding the meanings behind primary observations. Through the study of this meaning, the researcher can appreciate what people understand concerning a phenomenon. An important idea behind the interpretivist paradigm is that reality is socially constructed and therefore, what we understand is always negotiated within cultures, social settings, and relationships with other people.

With the interpretivist approach, the researcher is the primary data-gathering instrument where carefully constructed questions aimed at understanding a phenomenon through semi-structured or open-ended interviews are often used. Another characteristic of the interpretivist approach is that it can generate a significant amount of data about a small number of participants which is relevant for this study.

One way researchers can apply the interpretivist paradigm is through the use of the concept of perspectives. This concept involves the notions of aims and intentions, significance, reasons and strategies (Blackledge & Hunt, 1985). According to the Blackledge and Hunt (1985) framework for perspectives, four assumptions underpin the interpretivist approach to research. These assumptions involve everyday activity, freedom, meaning, interaction, and negotiation. Each of these assumptions has influenced this study and is discussed briefly.

The first assumption is that everyday activities are the foundation of society. If everyday activities are changed, it may eventually influence small changes in society. For example, a classroom keeps running based on the daily activities of the teachers and the students. If these activities are modified, changes in the lessons and subsequently in the education of the students will occur.

The second assumption states that there is usually some autonomy and freedom in everyday activities. This assumption means that everyday activities are usually not imposed or forced on the individuals involved. The individuals make decisions in determining these everyday activities, and they are independent to some extent in developing individualised patterns of activities (Blumer, 1969). In the context of this study, the teachers have the
autonomy to determine their everyday activities concerning the teaching of biology. However, their activities are usually decided in alignment with the prescribed school curriculum.

The third assumption is that everyday activities involve interactions between people rather than actions in isolation. Meanings are formed from these interactions as well as through historical and cultural norms. Therefore, it is important for the researcher to acknowledge the influence of her own personal, cultural and historical experience on the interpretation of the data presented (Creswell, 2005). This interpretation is represented in the data analysis of the interview data collected for the purpose of research question three.

The fourth assumption states that everyday activities involve negotiations which modify understanding and views. Perspectives are never stagnant. Instead, they are considered to be fluid and subject to change depending on the environment. Therefore, a common understanding or perspective may develop over time for people who operate regularly in a particular working environment. The perspectives of secondary school biology teachers are investigated and presented in Chapter Seven.

In summary, these four assumptions inform us of the importance of everyday activities to society. These everyday activities are influenced by individual decisions and interactions between people and the environment. These influences negotiate an individual’s understandings and views which in turn affect the individual’s perspectives. These assumptions underpin the interpretivist approach to this study.

2b. Symbolic interactionism

Symbolic interactionism is a major theoretical position within the interpretivist paradigm. It is both a theory and an approach to the study of human behaviour (O’Donoghue, 2007). People construct meaning by interpreting their social interactions (Bogdan & Biklen, 2007) and communicate these meanings. An important idea behind symbolic interactionism is that human interactions and actions can only be understood through meaningful communication. Blumer (1969) identifies five principles of symbolic interactionism:
The response of humans to a particular thing depends on the meaning that has been attached to it.

The meaning attached to things is greatly dependent on social interactions with peers.

The person uses the meanings in dealing with the things encountered.

The meanings are not rigid and can alter based on situations.

The meanings are also used to determine actions.

Symbolic interactionist studies can sometimes help to provide the necessary understanding that will allow appropriate decision-making. For example, Fullan (2007) contended that central level bureaucrats who are trying to promote change could benefit from reflecting on interpretivist studies. One value of theory developed through symbolic interactionist studies is in providing policymakers with an understanding of ground-level information and perspectives (O’Donoghue, 2007). Symbolic interactionism is extensively used in education and social research and is important to this study. It concerns how individuals react, make sense of, analyse and interpret any given situation.

3. Sampling

The first and second research questions involved an analysis of relevant documents and papers on the Singapore education system. The third research question was investigated by means of semi-structured interviews conducted with twelve teachers, three at a time, from four different secondary schools in Singapore.

3a. Document sampling

Data was required for two separate timelines, the period before independence (1920 – 1964) and the post-independence period (1965 – recent). The focus on educational policies and development with reference to the teaching of science and biology was used as a secondary filter. Documentary evidence from both primary and secondary sources was gathered and analysed. Examples of these are highlighted in the section on data collection methods.
To develop an understanding of the teaching of biology in secondary schools in Singapore, it is important to first understand the historical background of the education system in Singapore with special reference to the development of the teaching of science. The data collected from the time period before the 1920s was not substantial in providing a complete perspective of the historical background of the education system in Singapore. Therefore, because of this limitation, this study focuses on the historical background of the education system in Singapore after the 1920s to 1958 with special reference to the development of the teaching of science.

3b. Sampling of schools

For the third research question, four semi-structured interviews were carried out with a total of twelve teachers. The study was conducted in Singapore with participants consisting of biology teachers from four different government schools.

There are three different types of secondary schools in Singapore - government schools, government-aided schools, and independent schools. The structure of these schools was explained in Chapter Two. Government schools are fully funded by the government and follow the policies from the Ministry of Education. Government-aided schools are partially funded by the government and follow a slightly different framework for policy setting. Autonomous or Independent schools are not funded by the government and are given autonomy in the implementation of policies.

It was determined that the study is limited to four randomly selected government secondary schools in Singapore. This is because the three different types of schools in Singapore follow the same curriculum and syllabus as prescribed by the Ministry of Education in Singapore. Therefore it was ascertained that the researcher would achieve an in-depth study by focusing on the perspectives of the teachers from four randomly chosen government secondary schools.

The researcher experienced data saturation upon the fourth interview as the points iterated by the teachers were repeated and common. Qualitative samples must be large enough
to assure that most of the perspectives and opinions are uncovered, but not too large to the extent of repetitive opinions and insufficient new data (Mason, 2010).

3c. Sampling of participants

The sampling of participants was based on two important guidelines, purposeful sampling and maximum variation sampling (Merriam, 2009). Maximum variation sampling with variation in gender and years of teaching experience was used to select the teachers. Purposeful sampling was done by ensuring all the teachers interviewed were all trained in teaching biology to upper secondary school students and all the teachers possess at least a bachelor’s degree majoring in science from a local or foreign university. They had also attended a one-year compulsory preparatory course in biology teaching and pedagogy at the National Institute of Education, which awarded them a postgraduate diploma in education. Twelve teachers from four different secondary schools were interviewed. The details of the participants interviewed are listed in the table below.

Table 4.1

*Details of participants interviewed*

<table>
<thead>
<tr>
<th>School</th>
<th>Teacher</th>
<th>Gender</th>
<th>Years of teaching experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>School 1</td>
<td>Teacher 1</td>
<td>Female</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Teacher 2</td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Teacher 3</td>
<td>Male</td>
<td>2</td>
</tr>
<tr>
<td>School 2</td>
<td>Teacher 1</td>
<td>Female</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Teacher 2</td>
<td>Female</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Teacher 3</td>
<td>Female</td>
<td>2</td>
</tr>
<tr>
<td>School 3</td>
<td>Teacher 1</td>
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<td></td>
<td>Teacher 2</td>
<td>Female</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Teacher 3</td>
<td>Female</td>
<td>9</td>
</tr>
<tr>
<td>School 4</td>
<td>Teacher 1</td>
<td>Male</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Teacher 2</td>
<td>Male</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Teacher 3</td>
<td>Male</td>
<td>8</td>
</tr>
</tbody>
</table>
Participation was entirely voluntary. The first step was to obtain permission from the research and planning division at the Ministry of Education in Singapore to conduct the interviews. A copy of the research proposal and the ethics approval letter from The University of Western Australia were submitted as part of the application requirements. The second step involved sending out letters of invitation to the principals of the schools selected. Once approval had been granted by the principal, the teachers were contacted and received a letter of consent to sign as well as a letter outlining the study.

4. Data collection methods

4a. Document collection

As indicated, document analysis was used to address the first two research questions. Historical documents and contemporary documents of a primary and secondary nature were studied and analysed for this study. The study of documents is consistent with the interpretivist approach to inquiry. Interpretivists often adopt a descriptive analysis of historical documents to establish an understanding of the subject of research. The review of historical documents is one of the most effective methods of collecting data from the colonial period as historical events can no longer be observed (Bowen, 2009). Eliciting perspectives of teachers from that period was also ineffective as many of them are currently senior in age and are unable to recollect specific events from the period they were teaching.

For the period before independence, data was collected through historical review documents, annual reports or books by scholars, including Wilson (1978), Gopinathan (1974), Chen and Koay (2001) and Doraisamy et al., (1969). These scholars provided invaluable insight into the educational landscape during the colonial period and thereafter. Some of the important books used were “Inquiry into the Singapore Science Classroom, Research and Practice” by Tan, Lim and Poon (2014), “Examinations in Singapore, Change and Continuity (1891 – 2007)” by Tan et al. (2014), “Transforming Teaching, Inspiring, Learning. 60 years of Teacher Education” by Chen and Koay (2001) as well as “Towards a National System of Education in
Singapore. 1945 – 1973’ by Gopinathan (1974). These books provided several different perspectives into the development of the educational landscape of Singapore.

For the post-independence period, the evidence collected included publications and documents that made reference to the teaching of science in secondary schools in Singapore. This includes Singapore’s Ministry of Education work-plan seminar documents, as well as the Ministry’s annual reports, parliamentary debates and the Ministry of Education’s speeches in which policies are often announced and explained by the Minister of Education (Yap et al., 2008).

To further deepen the data collected, an interview was also conducted with a Professor from the National Institute of Education. She is the Deputy Head (Teaching and Curriculum Matters) for the Natural Sciences and Science Education faculty at the National Institute of Education in Singapore. She was also previously a biology teacher at a secondary school in Singapore. Her position previously as a secondary school biology teacher as well as currently, a professor in the National Institute of Education, provided further strengthening to the data collected and on the perspectives of teachers in response to research question three. The interview provided an additional perspective to this study and contextualised and provided significance to the educational policies described in this study, specifically the policies implemented after independence. The findings of this interview are presented in Chapter Seven.

4b. Interviews

Four semi-structured group interviews were conducted with three teachers each time so that a total of twelve teachers were interviewed. Semi-structured interviewing was chosen for three reasons; firstly, the participants are allowed to react and comment on the guiding questions (Major & Baden, 2010) without strict restrictions. This allowed the teachers to feel comfortable to share their perspectives; secondly, semi-structured interviews have proven to be optimal in providing "people's perceptions, meanings, definitions of situations and constructions of reality” (Punch, 2014, pg 144); thirdly, this type of interview allows the interviewer to pre-
determine the direction of the interview and elicit appropriate responses from the interviewee to ensure a valid set of data.

An interview guide was used to ensure that all the important and relevant topics were covered in a particular order during the interviews. The interview guide was developed through the guiding questions and through conversations with science teachers who were not part of the study. These teachers provided valuable feedback from an external perspective on the clarity and flow of the interview guide. The guide was periodically revised as the interviews progressed.

Face to face interviews were conducted from the period September 2015 to March 2016. As mentioned earlier, permission was granted from the research and planning division at the Ministry of Education in Singapore in September 2015. Permission was also requested from the principal and the teachers before the commencement of the interviews. Notes and recordings were taken during the interviews, and inductive inferences were made to allow the researcher guidance in determining further questions (Major & Baden, 2010). Each interview lasted for approximately 90 minutes. The recorded interviews were subsequently transcribed. Each participant was identified by a numerical code on the transcript to ensure anonymity.

5. Data analysis methods

Data for this study were analysed using the general qualitative data analysis method described by Miles and Huberman. The Miles and Huberman method describes a concurrent three-step process: data reduction; data display; and drawing and verifying conclusions. The method is briefly described below. Examples of the data analysis for research question one, two and three are given later in this chapter using extracts from the actual data.

5a. Data reduction

Data reduction or data condensation refers to the process of selecting, focusing, simplifying and abstracting the data without the loss of significant information (Punch, 2014). This is considered a primary form of analysis which focuses and divides the data allowing
themes and patterns to emerge. In the early stages, transcribing, editing and summarising the data allows for the initial data reduction. This is followed by finding themes and patterns through coding and memoing. In the later stages, data reduction involves the development of more complex and abstract concepts. Coding and memoing provide the foundation for the Miles and Huberman approach to data analysis.

Coding is a central activity in qualitative data analysis. Coding is a data condensation tool that allows the researcher to locate the important material in the data. Codes are first assigned to large amounts of data to detect reoccurring patterns (Miles & Huberman, 2014). This allows a fixed set of patterns to be identified through this method of categorization. As more data is collected, there is a constant comparison and questioning of data which will allow for the emergence of new themes and patterns (Merriam, 2009). There are two cycles of coding to the data analysis: first cycle coding, which involves the emergence of descriptive codes; and second cycle coding which produces pattern codes. Basically, the process of coding involves the introduction of labels to the data and therefore categorising them.

Descriptive codes involve coding which attaches a summary to the data and categorises the data according to broad themes. Descriptive codes require a minimal amount of inference and are based on the data itself. Descriptive codes allow the researcher to establish a valuable insight into the initial presentation of the data. This first level coding provides the basis for higher level inferential coding.

Pattern codes involve this higher level of inference and analysis. Pattern codes bring a large number of descriptive codes into a smaller number of pattern codes (Punch, 2014). Hence they are an inductive development from descriptive codes. A summary of the descriptive and pattern codes from the data obtained is presented in Chapter Seven.

Memoing is another important stage of analysis. Coding and memoing are not necessarily sequential in their application. Memoing allows a higher level of analysis from the concepts obtained through coding. Memos may be substantive, theoretical, methodological or personal (Punch, 2014). Memoing allows the researcher to be creative and speculative.
However, speculative concepts based on data require verification through the drawing of meaning and conclusions.

After coding and memoing, meanings and conclusions are drawn from the numerous memos and codes established. The objective of this stage, which is often considered the last stage, is to provide a coherent and meaningful understanding from the data analysed. There are two different phases in the last stage: drawing or generating meaning; and testing or confirming findings (Miles & Huberman, 2014).

5b. Data display

Data display involves analysing and organising the data in a presentable format. By displaying the data, the stages of analysis are shown. This allows the researcher to determine the areas required for further analysis. Sound qualitative data analysis involves repeated and iterative displays of data (Punch, 2014). The display format is highly dependent on the objective of the researcher and the stage which the study has reached. There are several forms of data display described by Miles and Huberman, (2014). For the purpose of this study two forms of data display, matrices and networks were used. A matrix is essentially the intersection of two lists, set up as rows and columns, whereas a network is a collection of nodes or points which are connected.

5c. Drawing and verifying conclusions

Drawing and verifying conclusions is the third part of the Miles and Huberman approach to data analysis. The process of drawing conclusions begins early in the coding process. Important phenomena and propositions related to these phenomena are generated upon the initial reviewing of the data. The relationships between these propositions appear at the initial stage as well. Conclusions drawn from earlier analysis require refinement as they usually appear vague at first (Punch, 2014). The initial conclusions remain open to interpretation and amendments. Once all the data is analysed, the conclusions are verified and become more grounded.
The Miles and Huberman method of data analysis was used to analyse both types of data for this study. The historical data obtained for research question one and two were selected and simplified. This allowed the researcher to draw and verify conclusions which were used to discuss the historical background and the recent developments to the education system in Singapore. This is further discussed in Chapter Five and Six. The interview data were transcribed and subsequently reduced using memos and codes. This allowed an accurate display of the data which led to drawing and verifying of conclusions. This is explained in Chapter Seven. The data analysis for this study informed the researcher of propositions which emerged through the drawing of conclusions. These propositions are presented in Chapter Eight.

6. Developing the research questions

6a. The first research question

The first research question sought to develop an understanding of the historical background of the education system in Singapore from the colonial times (1920) until the pre-independence period (1958), with special reference to the development to the teaching of science in secondary schools. The study is exploratory, therefore, the guiding questions that arose to guide the study for the first research question are not exhaustive. The guiding questions are set out in Table 4.2.
Table 4.2

The development of guiding questions from the first central research question.

<table>
<thead>
<tr>
<th>Central research question</th>
<th>Guiding questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The development of guiding questions from the first central research question.</td>
<td></td>
</tr>
<tr>
<td>What is the historical background to the education system in Singapore from the colonial</td>
<td>1.1 What influenced the development of the educational system in Singapore during</td>
</tr>
<tr>
<td>times (1920) until the pre-independence period (1958), with special reference to the development of the teaching of science in secondary schools?</td>
<td>the colonial period until the pre-independence period?</td>
</tr>
<tr>
<td>1.1 What influenced the development of the educational system in Singapore during the</td>
<td>1.2 How did the state of governance during the colonial period until the pre-</td>
</tr>
<tr>
<td>colonial period until the pre-independence period until the pre-independence period,</td>
<td>independence period, impact the development of the educational system in Singapore?</td>
</tr>
<tr>
<td>impact the development of the educational system in Singapore?</td>
<td>1.3 What were the principles or objectives behind the specifically chosen structure for the educational system in Singapore during the colonial period until 1958?</td>
</tr>
<tr>
<td>1.4 How did certain educational policies impact the development to the teaching of science</td>
<td>1.4 How did certain educational policies impact the development to the teaching of</td>
</tr>
<tr>
<td>in secondary schools?</td>
<td>science in secondary schools?</td>
</tr>
<tr>
<td>1.5 What were the principles or objectives behind the specifically chosen structure for</td>
<td>1.5 What were the principles or objectives behind the specifically chosen structure for the teaching of science in Singapore during the colonial period until 1958?</td>
</tr>
<tr>
<td>the teaching of science in Singapore during the colonial period until 1958?</td>
<td></td>
</tr>
</tbody>
</table>

These guiding questions have the potential to provide the most data concerning this research question. This was determined through conversations with teachers and research on the scope of the historical materials.

More specific questions (Punch, 2009) were developed from the guiding questions. An example of the initial aide-memoire developed from the guiding questions from the first central research question is given in Table 4.3 below.
Table 4.3

The development of aide-memoire questions from the first guiding question of the first central research question.

<table>
<thead>
<tr>
<th>Guiding question</th>
<th>Examples of questions from the initial aide-memoire</th>
</tr>
</thead>
<tbody>
<tr>
<td>What influenced the development of the educational system in Singapore during the colonial period until the pre-independence period?</td>
<td>1.1.1 What laws, policies and practices governed the education system in Singapore?</td>
</tr>
<tr>
<td></td>
<td>1.1.2 Who were the stakeholders or decision makers involved in shaping the education system?</td>
</tr>
<tr>
<td></td>
<td>1.1.3 What were the political developments that may have influenced the development of the education system concerning the development of the teaching of science?</td>
</tr>
</tbody>
</table>

Similar aide-memoire questions were developed for the other guiding questions. These questions assisted the researcher in focusing the study.

**Example of analysis for the first research question.**

The process of descriptive and pattern coding according to the Miles and Huberman approach to data analysis is outlined in Table 4.4 below. The report from the commission appointed by the Secretary of State for the colonies on Higher Education in Malaya\(^1\) is used to address guiding question 1.1.

---

\(^1\) The term British Malaya loosely describes a set of states on the Malay Peninsula and the island of Singapore that were brought under British control between the 18th and the 20th centuries.
Table 4.4

Coding of a document gathered in the course of examination of documentary data concerning the first research question.

<table>
<thead>
<tr>
<th>Document text</th>
<th>Descriptive codes</th>
<th>Pattern codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>We discuss the difficulties on the teaching of English in the schools and make suggestions calculated to effect improvement. The place of the study of English literature in the schools is considered. We recommend that the study of set books for examination purposes be discontinued, and that in future the examination in English in the School Certificate should be one in English language only, and that the present special examination in English language and literature be discontinued.</td>
<td>Teaching the English language</td>
<td>English competency</td>
</tr>
<tr>
<td></td>
<td>The teaching of English literature</td>
<td>English competency</td>
</tr>
<tr>
<td></td>
<td>Recommendation</td>
<td>Colonial influence</td>
</tr>
<tr>
<td></td>
<td>Exams in English</td>
<td>English competency</td>
</tr>
<tr>
<td></td>
<td>Discontinuation of special exams in English</td>
<td>Colonial influence</td>
</tr>
<tr>
<td>We discuss in detail the place of science teaching in the Secondary Schools. We recommend that the system of teaching science in certain central schools be discontinued; that every secondary school should teach general science up to and not beyond School Certificate standard, and there should be no separate teaching of Chemistry, Physics, and Biology. We recommend that the teaching of Hygiene as a separate subject be discontinued and that Hygiene is taught in relation to Biology as part of the general science course. In consequence, general science including hygiene should be taken as a subject for the School Certificate Examination instead of Hygiene.</td>
<td>Recommendation</td>
<td>Colonial influence</td>
</tr>
<tr>
<td></td>
<td>General science in all schools</td>
<td>Science teaching</td>
</tr>
<tr>
<td></td>
<td>No higher science</td>
<td>Science teaching</td>
</tr>
<tr>
<td></td>
<td>Recommendation</td>
<td>Colonial influence</td>
</tr>
<tr>
<td></td>
<td>General science</td>
<td>Science teaching</td>
</tr>
<tr>
<td></td>
<td>Assessment in general science</td>
<td>Science teaching</td>
</tr>
</tbody>
</table>

Note - The document is an extract from the Report of the Commission appointed by the Secretary of State for the colonies on Higher Education in Malaya (the McLean Report), 1939.

6b. The second research question

The second research question aims to develop an understanding of the recent developments since 1959 that had taken place in relation to the teaching of science in secondary schools in Singapore with special reference to the teaching of biology. The guiding questions are set out in Table 4.5.
Table 4.5

The development of guiding questions from the second central research question.

<table>
<thead>
<tr>
<th>Central research question</th>
<th>Guiding questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the recent developments of the education system pertaining to the teaching of science in secondary schools in Singapore from 1959 to recent times, with special reference to the teaching of biology?</td>
<td>2.1 What were the influences behind the development of the current educational structure concerning the teaching of science and biology in secondary schools in Singapore from 1959 until recent times?</td>
</tr>
<tr>
<td></td>
<td>2.2 What were the principles or objectives behind the specifically chosen structure concerning the teaching of science and biology in secondary schools in Singapore from 1959 until recent times?</td>
</tr>
<tr>
<td></td>
<td>2.3 What are the advantages and disadvantages perceived from the educational system implemented in Singapore from 1959 until recent times concerning the teaching of science and biology in secondary schools?</td>
</tr>
</tbody>
</table>

An example of the initial aide-memoire developed from the guiding questions from the second central research question is given in Table 4.6 below.

Table 4.6

The development of aide-memoire questions from the first guiding question of the second central research question.

<table>
<thead>
<tr>
<th>Guiding question</th>
<th>Examples of questions from the initial aide-memoire</th>
</tr>
</thead>
<tbody>
<tr>
<td>What were the influences behind the development of the current educational structure concerning the teaching of science and biology in secondary schools in Singapore from 1959 until recent times?</td>
<td>2.1.1 What laws, policies and practices governed the education system in Singapore concerning the teaching of science and biology in secondary schools?</td>
</tr>
<tr>
<td></td>
<td>2.1.2 What were the political developments that may have influenced the development of the teaching of science and biology in secondary schools in Singapore?</td>
</tr>
<tr>
<td></td>
<td>2.1.3 Who were the stakeholders or decision makers involved in shaping the education system concerning the teaching of science and biology in secondary schools in Singapore?</td>
</tr>
</tbody>
</table>

Example of analysis for the second research question

An example of descriptive and pattern coding is given in Table 4.7. The final report from the commission of inquiry into education conducted in 1964 was used to address guiding question 2.1.
Table 4.7

*Coding of a document gathered in the course of examination of written data concerning the second research question.*

<table>
<thead>
<tr>
<th>Document text</th>
<th>Descriptive codes</th>
<th>Pattern codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion with teachers of Science reveals that there is a diversity of opinion about the present curriculum. Some think that it is too wide and too ambitious to be adequately covered in the six periods per week allocated. Others feel that too much stress is placed on what is useful for examinations, leaving out the main emphasis of science teaching, namely, instilling the spirit of inquiry.</td>
<td>Wide curriculum</td>
<td>Curriculum</td>
</tr>
<tr>
<td></td>
<td>Insufficient time</td>
<td>Logistic</td>
</tr>
<tr>
<td></td>
<td>Emphasis on</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>examinations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spirit of inquiry</td>
<td>Inquiry</td>
</tr>
<tr>
<td>Our observations point to a defect to the objects of science teaching. Some teachers insist on covering 'so many pages' of the textbook per session and force pupils to do experiments of a 'verifying' nature. The possibility of finding a solution (or some solutions) to a given problem is forgotten. Beautiful diagrams and formulae are drawn on blackboards and demonstrations are arranged by the teacher, but here again, it is often to show 'proof' of a statement, and not to discover the underlying principles through first-hand observations by the pupils themselves. The result is that the pupils think of the laboratory session as a necessary chore, not of great value, to be ‘dodged’ or ‘palmed off’ to one’s partner, whenever possible.</td>
<td>Objectives of science</td>
<td>Curriculum</td>
</tr>
<tr>
<td></td>
<td>Too much content</td>
<td>Curriculum</td>
</tr>
<tr>
<td></td>
<td>Lack of inquiry</td>
<td>Inquiry</td>
</tr>
<tr>
<td></td>
<td>Teacher-centered</td>
<td>Pedagogy</td>
</tr>
<tr>
<td></td>
<td>Lack of inquiry</td>
<td>Inquiry</td>
</tr>
<tr>
<td></td>
<td>Teacher-centered</td>
<td>Pedagogy</td>
</tr>
<tr>
<td></td>
<td>Lack of inquiry</td>
<td>Inquiry</td>
</tr>
</tbody>
</table>

*Note* - The document is an extract from the Final Report of the Commission of Inquiry into Education conducted in 1964. This report is utilised in addressing Guiding Question 2.3: What were the influences behind the development of the current educational structure concerning the teaching of science and biology in secondary schools in Singapore from 1959 until recent times?
6c. The third research question

The third research question sought to investigate the concerns and perspectives of secondary school biology teachers. Data for this question was obtained through four semi-structured interviews conducted with a total of twelve secondary school biology teachers from four different schools. The Blackledge and Hunt (1985) framework for perspectives informed the work of the researcher. This concept involves the notions of aims and intentions, significance, reasons and strategies (Blackledge & Hunt, 1985). The Blackledge and Hunt (1985) framework for perspectives was useful in framing the interview guide which was developed from the guiding questions. The interview guide was periodically revised as the interviews progressed. The guiding questions are set out in Table 4.8 below.

Table 4.8

The development of guiding questions from the third central research question.

<table>
<thead>
<tr>
<th>Central research question</th>
<th>Guiding questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What issues are currently of concern to secondary schools’ biology teachers and what perspectives do they have regarding the teaching of biology in Singapore secondary schools?</td>
<td>3.1 What are the aims and intentions of the teachers regarding the teaching of biology in secondary schools in Singapore?</td>
</tr>
<tr>
<td></td>
<td>3.2 What are the strategies employed by secondary school teachers in Singapore who teach Biology?</td>
</tr>
<tr>
<td></td>
<td>3.3 What is the significance of the strategies employed by secondary school teachers in Singapore who teach Biology?</td>
</tr>
<tr>
<td></td>
<td>3.4 What are the challenges that teachers face regarding the teaching of biology in secondary schools in Singapore?</td>
</tr>
</tbody>
</table>

An example of the initial aide-memoire developed from the first guiding question from the third central research question is detailed in Table 4.9 below.
Table 4.9

The development of aide-memoire questions from the first guiding question of the third central research question.

<table>
<thead>
<tr>
<th>Guiding question</th>
<th>Examples of questions from the initial aide-memoire</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the challenges that teachers face regarding the teaching of biology in secondary schools in Singapore?</td>
<td>3.1.1 How do these challenges affect the teaching of biology in secondary schools in Singapore?</td>
</tr>
<tr>
<td></td>
<td>3.1.2 What are some of the strategies employed in managing these challenges?</td>
</tr>
<tr>
<td></td>
<td>3.1.3 What is the significance of these challenges in managing the teaching of biology in secondary schools in Singapore?</td>
</tr>
</tbody>
</table>

Example of analysis for the third research question

An example of descriptive and pattern coding is given in Table 4.10. An excerpt from the interview transcript from one of the interviews conducted on the 5th October 2015 was used.
Table 4.10

*Coding of interview transcript 1*

<table>
<thead>
<tr>
<th>Interview text</th>
<th>Descriptive codes</th>
<th>Pattern codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: What are some challenges affecting the teaching of biology in secondary schools? Let’s start with logistical challenges.</td>
<td>Lack of equipment</td>
<td>Logistics</td>
</tr>
<tr>
<td>T: For exploration, we do lack equipment. For example, we do not have an electron microscope. Let’s say we go into genetics. We do not have the equipment to do, for example, polymerase chain reaction or PCR techniques. We could resolve that by going to a polytechnic to collaborate with them. However, that requires an entire learning journey for the students which we do not have time for.</td>
<td>Lack of inquiry</td>
<td>Curriculum</td>
</tr>
<tr>
<td></td>
<td>Source for equipment</td>
<td>Logistics</td>
</tr>
<tr>
<td></td>
<td>Insufficient time</td>
<td>Logistics</td>
</tr>
<tr>
<td>I: What about challenges with the curriculum?</td>
<td>Introduction to molecular genetics.</td>
<td>Curriculum</td>
</tr>
<tr>
<td>T: The introduction of molecular genetics into the curriculum was quite a challenge. It becomes very stressful for teachers because re-learning has to take place. We have all been trained in a particular field, but when new science comes in, we are expected to re-learn a large amount of knowledge. We relied on textbooks and the internet mostly, to update ourselves regarding the content. Moreover, of course, we helped one another. We did not have the time to attend courses.</td>
<td>Stressful.</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>Re-learning</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>Teacher competency</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>New science introduced</td>
<td>Curriculum</td>
</tr>
<tr>
<td></td>
<td>Self-learning through</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>textbooks</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>Re-learning</td>
<td>Support</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>Challenges</td>
</tr>
<tr>
<td></td>
<td>Self-taught</td>
<td>Support</td>
</tr>
<tr>
<td></td>
<td>Teacher support</td>
<td>Logistics</td>
</tr>
<tr>
<td></td>
<td>Insufficient time to attend courses</td>
<td></td>
</tr>
</tbody>
</table>

Note - This is an excerpt from the transcript of an interview held on 5th October 2015 with School 1, in addressing guiding question 3.4: What are the challenges that teachers face regarding the teaching of biology in secondary schools in Singapore?
7. Ethical considerations

This section addresses the ethical considerations of the study. The study proposal was approved by The University of Western Australia’s Human Research Ethics Committee. Permission to conduct the interviews was also granted by the Ministry of Education of Singapore for a period of six months from September 2015 to March 2016. All participants were assured of anonymity and confidentiality. No details of the participants will be released. As mentioned, the first step was to obtain permission from the Ministry of Education in Singapore to conduct the interviews. The second step involved sending out letters of invitations to the principals of the schools selected. Once approval had been granted by the principal, the teachers were contacted and received a letter of consent as well as a letter outlining this study. The participants were assured that their interview data would only be used for the purpose of this study.

This chapter has described the research methods used in this study. The theoretical framework explaining the research paradigm and the theoretical perspective was discussed. Secondly, the sampling of documents, schools, and teachers was described and thirdly the data collection methods were reported, followed by the data analysis methods.

The findings of the study are presented in the next three chapters. Chapter Five presents the findings generated from the research on the historical development of the education system in Singapore with special reference to the teaching of science in secondary schools from 1920 to 1958. Chapter Six describes the findings generated from the research on the recent developments of the education system concerning the teaching of science in secondary schools in Singapore with special reference to the teaching of biology. Chapter Seven illustrates the perspectives and concerns of secondary school teachers regarding the teaching of biology in Singapore which emerged during the interviews conducted with the teachers. After that, chapter Eight concludes the study, presenting propositions which were developed through the data analysis of this research.
CHAPTER FIVE
HISTORICAL BACKGROUND

1. Introduction

Chapter Five aims to develop an understanding of the historical background to the education system in Singapore from the colonial times (1920) until the pre-independence period (1958) with special reference to the development of the teaching of science in secondary schools. This is in response to the first research aim of this study.

Despite the existence of science education in some schools in Singapore, it was strictly controlled during the colonial period (Ho, 1952). It was not readily available to all schools, as will be described in this chapter. The introduction of vocational and technical education during the Japanese occupation stimulated the development of science education in Singapore which eventually contributed to the development of the teaching of science in secondary schools. Biology, a specialised subject within science, was introduced after a foundation was developed in the area of science education. This was observed after 1958 and will be described in Chapter Six.

There were two limitations in the research of this chapter. Firstly, much of the available literature on Singapore’s education system during the colonial times focuses on the 20th century rather than the early 19th century. This study is therefore limited to educational developments during the 20th century, in particular, the period after 1920. Secondly, the primary sources provided a structural understanding of the education system during the colonial period; however, a reliance on the secondary sources was required to develop an understanding of the people’s response to the educational policies and the resultant impact on the society.

There were three significant stages of government from 1920 to 1958. They were the colonial times from 1920 to 1942, the Japanese occupation from 1942 to 1945 and the pre-independence stage from 1946 to 1958. Each regime attempted to implement its ideology and educational strategies to address the education problems in Singapore. The educational reforms brought about by these three stages had a significant impact on the development of the
education system in Singapore as well as on the direction the education system eventually adopted. This chapter describes each of the three stages with an overview of the historical, political and social climate in Singapore at that time.

This chapter begins with the significance of research question one to this study. This is followed by a description of the historical background of the education system during the colonial times (1920 – 1941) with an emphasis on the structure of vernacular schools and its impact on the education system. The third part describes the historical background of the education system during the Japanese occupation (1942-1945) with an emphasis on the introduction of vocational and technical education. Lastly, the historical background of the education system during the pre-independence period (1946 – 1958) is described, with an emphasis on the impacts of the Ten Year Programme and the All Party Report. Within each section, a description of the development of the teaching of science is included where applicable.

2. Significance

Education in Singapore acts as an instrument of its economic policies and nation-building (Blackburn, 2017). Singapore’s education academics, such as Gopinathan (1974) and Blackburn (2017), have labelled this as the education–economy nexus or relationship. According to Gopinathan (1974), the educational policies adopted in Singapore reflect an education-economy relationship. The implementation of these policies aims to build a skilled workforce in alignment with the demands of the economy. This was seen as necessary in Singapore due to its limited natural resources and its heavy reliance on its human workforce (Gopinathan, 1974). As the country progressed to an economy driven by skilled labour, there was a greater emphasis on science and technology in the curriculum. Through this, Singapore was able to achieve “a tight coiling of education and training systems with state-determined economic policies” (Gopinathan, 2013, p.40). This contributed to Singapore’s economic success despite its limited natural resources.
As mentioned earlier, there were three stages of government during the period of 1920 to 1958. Each stage of government saw a different interpretation of the education-economy relationship. The education-economy relationship during the colonial administration focused on an economy of trade. Therefore, the education system centred on low-level skilled labour. The introduction of vocational and technical education was observed during the Japanese occupation in response to a manufacturing economy. This introduction stimulated the development of the teaching of science during the pre-independence period.

3. Colonial period (1920 – 1941)

The historical background of the colonial period will be described first, followed by a description of the educational structure, in which the vernacular education system will be highlighted. The impact on the teaching of science is then described.

3a. Historical background

Sir Stamford Raffles founded Singapore in 1819 when it became part of the East India Company governed by the colonial administration. The East India Company was eventually divided into two separate colonies - The Federated Malay States and the Straits Settlement. Singapore was part of the Straits Settlement which was established in 1826. The Federated Malay States and the Straits Settlement followed similar government policies and protocols regardless of the circumstances in each country (Wong & Gwee, 1972).

Singapore saw an influx of migrants from China and India during the colonial period. The wealthy migrants invested mainly in the development of their own racial communities including the development of schools. A nation with people of different backgrounds, different languages and different customs and beliefs developed with the arrival of migrants. It was necessary to develop national unity in Singapore to address the inherent weakness and strains that were developing from its pluralistic society (Gopinathan, 2013). However, policies and administrative processes from the colonial administration appeared to be a series of improvisations based on circumstances (Ho, 1952) and did not address the problems arising
from its pluralistic society. A decentralised education system developed during the colonial administration, with different types of schools implementing different curriculums.

As the world moved into an economy with a demand for a skilled workforce, it might have been in the country’s best interest to invest in vocational and technical education during the 1920s (Blackburn, 2017). It could have possibly transformed the economy of Singapore by providing a skilled workforce in the area of engineering and manufacturing. However, according to Goh (2013), the number of colonial educational institutions introduced in the 1920s, even though useful and significant in intention, was too small and too limited in educational outreach to effectively impact Singapore’s economy during the period of 1920 to 1950. However, it is important to note that the colonial administration’s objective in Singapore was to maintain colonial order rather than to transform the economy. The colonial administration appeared satisfied with growing the economy in Singapore based on trade (Blackburn, 2017). Therefore, little effort was made in increasing the outreach and the numbers of these schools.

Despite the apparent lack of structured administration in the 1920s, the educational policies implemented by the colonial administration after the Japanese occupation during the pre-independence period (1946 – 1958) did lay the foundation for the postcolonial institutions of industrial training in the 1950s. This would provide an important link between industry and education of the Singapore economy (Blackburn, 2017), reflecting the education-economy relationship mentioned earlier.

3b. Structure of the education system

The administrative control of educational policies in the Straits Settlement was assigned to a single civil service officer, known as the Director of Education. Three individuals assisted him, one covering each of Malay schools, English schools, and Chinese schools. There was also an Inspector of Schools whose duties were mainly managerial or administrative.
There were English language schools, and vernacular schools, namely the Malay language schools, Tamil language schools, and Chinese language schools. Vernacular schools refer to schools where lessons were conducted in the native languages of the main resident communities, namely Malay, Chinese, and Tamil. There was no common curriculum or resources for Chinese and Tamil schools which were mainly privately funded by wealthy migrants. Grants and donations from within the respective ethnic communities sustained the running of these schools. Only the English and Malay language schools were government supported and therefore followed a centralised curriculum. The development of a uniform policy and system of procedures within education was observed only after the Second World War in the 1950s.

According to Wilson (1978), the absence of a unified policy of education led to a general sense of inequality of treatment amongst the races as well as a lack of opportunity in the areas of employment and education. Vernacular schools, which are described in the next section, contributed to the lack of a unified education system in Singapore.

**Vernacular schools.**

As mentioned, vernacular schools refer to schools where lessons were conducted in the native languages of the main resident communities, namely Malay, Chinese, and Tamil. The colonial administration placed importance on the fact that the initial stages of education should be in the mother tongue languages of the locals. This led to a divergence in the type of schools in Singapore and the type of support given to these schools. As mentioned earlier, there was more support provided to the English and Malay schools rather than the Chinese and Tamil schools (Chen & Koay, 2001). With such an unequal provision of support, the educational progression of these schools was varied. Students were progressing educationally at different rates, and this was regarded as unfair and unacceptable. This was also true for the progression of scientific knowledge in the students. Some schools were well equipped with competent science teachers and facilities, while other schools were not even able to offer the teaching of science due to logistical limitations such as the unavailability of competent science teachers. The
teachers in the Chinese and Tamil medium schools were not trained to the level of the teachers at the English and Malay medium schools (Chen & Koay, 2001). This resulted in accentuated divisions in Singapore society, a society that was already struggling to find common grounds amongst the numerous migrants (Gopinathan, 1974). Historians such as Gopinathan (1974) and Ho (1952) considered this division as detrimental to the progress of the nation.

As stated by Cheeseman (1938), the colonial administration did not prioritise the training of the teachers in the Chinese and Tamil language schools. The training was independently administered at each vernacular school. There were a limited number of Tamil language schools with low enrolment during the colonial administration. Therefore there is limited mention of the Tamil language schools in historical data other than their existence.

The Chinese language schools, in contrast, were more in numbers and enrolment. Their educational outreach was more significant and was well documented. Chinese schools received funding from the Chinese government in China. Through their teachers, who were recruited and trained in China, the Chinese students were educated with a politically driven curriculum (Lee, 2006). An integral part of the Chinese education system in overseas communities such as Singapore was patriotism towards China and this was reflected in many of the Chinese schools’ resources and textbooks (Tan, 1997).

The colonial administration was not against the patriotism displayed amongst the Chinese students. However, a political divide developed when the Chinese students had begun expressing opinions and perspectives that were prejudicial and detrimental to colonial influence in Singapore (Lee, 2006). In response to the increasing political divide between the Chinese schools and the colonial administration, the Straits Settlement Legislative Council introduced an Education Ordinance in 1920 (Tan, 1997). The Ordinance sought to register both schools and teachers to re-establish government control over vernacular schools. This was mainly to eliminate schools and teachers possessing undesirable political ideologies. In an attempt to further control the education system, the Ordinance introduced grants-in-aid with certain clauses such as a condition that the schools followed a curriculum determined by the colonial
administration (Lee, 2006). This was noted to be one of the first steps by the colonial administration in developing a unified educational system.

The Malays were considered the natives of the island. Therefore there was a specific interest in the Malay language schools. A teacher training college was started in 1922 in Perak known as the Sultan Idris Training College. Training of teachers for Malay language schools in the Straits Settlement was conducted here and it was considered the distribution centre of knowledge for all Malay vernacular schools in the Straits Settlement (Winstedt, 1923).

Despite the apparent support, the Malays developed a dissatisfaction for the colonial administration. A speech made by Inche Mohamed Unus bin Abdullah in the Legislative Council on the 23rd of October 1929 reflected this dissatisfaction regarding educational policies imposed by the colonial administration.

In the fewest possible words, the Malay boy is told: "You have been trained to remain at the bottom, and there you must always remain." Why, I ask, waste so much time to attain this end when without any vernacular school, and without any special effort, the Malay boy could himself accomplish this feat? (Ho, 1952, pg. 110)

According to Winstedt (1943), the Malays were essentially unhappy with the progress of their education. The control and support that the colonial administration provided worked to the disadvantage of the Malays due to the restrictions on many things, most importantly, the control of the teaching of the English language. English was not widely taught and the lack of proficiency of the English language prevented the Malays from job opportunities and further progress in their education. English was only taught in Malay schools after World War Two when new educational policies were implemented.

As mentioned earlier, the teaching of science was not available to all schools (Ho, 1952). Based on the literature reviewed during the colonial period, there was evidence of the teaching of science only in English medium schools. Science laboratories and facilities were also noted to be present in only English medium schools.
The English language was slowly becoming the lingua franca of the country during the 1930s, and it could have been a great advantage for the locals if the learning of the language was prioritised. However, the colonial administration believed very firmly in controlling the spread of English education in the Straits Settlement (Gopinathan, 1974). Therefore, the advantage of the English language was not extended to all within the settlement (Ho, 1952). The reasons for this approach towards English education by the colonial administration were not articulated in the primary sources that were examined for this study such as the annual reports of the Straits Settlement. However, secondary sources cited speculation that the knowledge of the English language was controlled because of the fear of loss of power by the colonial administration. The colonial administration equated the proficiency of the English language with the gaining of employment.

According to Whitehead (2005), a historian of colonial education, the colonial administration was also apprehensive of an uncontrolled expansion of English-medium schools without the availability of suitable job positions. A similar situation arose in India in which English educated Indians were left unemployed due to a shortage of clerical job vacancies. The unemployed Indians blamed the colonial administration for their situation of unemployment. The colonial administration, therefore, wanted to avoid making a similar mistake which may cause resentment towards the colonial administration (Blackburn, 2017).

3c. Science education

As mentioned earlier in this chapter, the education-economy relationship is an important aspect of the development of the education system in Singapore. Education under the colonial administration was an instrument of the state (Blackburn, 2017). In other words, education was an avenue for the colonial administration to promote economic growth through trade. However, this instrumentalization of education served the colonial economy, rather than the economy of Singapore. According to Blackburn (2017), a focus on industrialisation of the economy could have resulted in an increased emphasis on the teaching of science through
vocational and technical education. However, as will be described later in this section, this was a much-debated issue during the colonial period.

The earliest evidence of science teaching in Singapore was in a Malay Missionary School established by Reverend Benjamin Peach Keasberry of the London Missionary Society in 1840 (Doraisamy et al., 1969). However, the school had a small candidature and it was closed in 1875 when Reverend Keasberry died. Science was taught in the form of vocational and technical education in the Malay Missionary School in 1840. This effectively amounted to the education of knowledge and skills for employment. The link between the economy and education was on the minds of the colonial administrators in the late 1930s (Blackburn, 2017) and a shift in the economy was inevitable. Vocational and technical education became a viable option to address the needs of the economy as well as to provide more employment opportunities for the local population.

In 1938, the colonial government commissioned a new report into vocational and technical education from H.R. Cheeseman, Inspector of Schools in Singapore (Blackburn, 2017). The committee focused primarily on science teaching in English secondary schools, and therefore the recommendations and the observations of the committee were not reflective of the science teaching, if any, in the vernacular schools during the colonial administration. The report, however, was significant in highlighting the change in perspective towards science teaching during the colonial administration, particularly from 1938 to 1941.

In the report of the committee published in February 1939 (Blackburn, 2017), it was recommended that science form an integral part of the curriculum of secondary schools. Unanimous recommendations were made regarding the extension of science teaching and the adoption of a general science syllabus in all secondary schools. The importance of learning science was highlighted in the report, citing its relevance to industrial development as well as to personal welfare such as hygiene. It was recommended that the science curriculum focus on agriculture and hygiene.
Raffles Institution, an English medium school, was the only English school in 1938 which had lecture rooms and science laboratories which were fully equipped for effective teaching of science (Chelliah, 1960). Therefore, it was also recommended that there should be more provision to other English schools to finance the logistical requirements for science teaching. In addition, the report highlighted the importance of employing the teaching expertise of trained individuals in implementing the science curriculum.

It is significant to note that through the recommendations of the committee, the teaching of science was slowly receiving increasing prominence during this period. There was an awareness of the lack of provisions for the teaching of science and recommendations were made to improve this. The recommendations of the committee were adopted in 1941 and were to be implemented that year. However, the onset of World War Two brought all educational plans to a halt (Winstedt, 1925) and they were only revisited after the war.

In addition to Cheeseman’s report, Professor G. McOwan, a teacher at a post-secondary institution, Raffles College, recommended introducing engineering courses (McOwan, 1938). He believed that by providing an increase in vocational and technical education at a post-secondary level, there would be an opportunity for educational progression for these students. Despite Cheesemans’s and McOwan’s recommendations, the colonial administration still debated the concept of increasing the vocational and technical education opportunities in Singapore and very little was done to this aspect before World War Two (Blackburn, 2017).

Singapore fell to the Japanese in February 1942 and the Japanese occupation of Singapore began. It lasted three and a half years from February 1942 to September 1945. Despite the short occupation, the Japanese made significant changes to the education system in Singapore. The intention of introducing vocational and technical education to Singapore was realised during the Japanese occupation and this had a significant impact on the teaching of science.
4. The Japanese Occupation (1942 – 1946)

4a. Historical background

Before 1942, Singapore was considered Britain’s impregnable fortress (Lee, 2005) and was of great importance to the colonial administration because of its strategic location as a port. However, Singapore’s defences were insufficient in preventing the entry of the Japanese (Lee, 2005) during the Japanese invasion of Singapore during World War Two. The Japanese occupation of Singapore lasted three and a half years from February 1942 to September 1946. The Japanese adopted a different approach towards education as compared to the colonial administration. There was an increased emphasis on vocational and technical education and a focus on science and economics.

The education-economy relationship was an important aspect of educational development in Singapore. During the Japanese occupation, the economy evolved from one based on entrepot trade to an economy that required more industrial workers to satisfy a manufacturing economy. After the war, these workers provided the basis of a small skilled industrial workforce that supplied the growing manufacturing sector of Singapore’s economy (Blackburn, 2017).

4b. Structure of the education system

The Japanese were cognisant that purposeful educational policies would instil a sense of loyalty amongst the locals in Singapore because they were confident that the younger generation would be able to drive the change in mindset that they needed (Lee, 2005). Therefore, educational policies were designed to ensure cultural cohesion between the Japanese and the local cultures. Education was also used to build on industrial and technical development.

Mamoru Shinozaki, a Japanese man who was on the staff of the Japanese Consulate in Singapore, was asked to take charge of the education department in Singapore. He had no previous experience in educational development or policy-making and had a tumultuous task.
ahead of him (Wilson, 1978). He faced three immediate problems upon the appointment of his role in Singapore.

The first problem he faced was a large number of school-going children who were contributing to the lawlessness of the country through petty theft and rowdiness. This was due to the fact that the schools were still closed after the war. There was a growing need to re-open the schools, particularly the primary schools, to ensure these children were in school and not on the streets. By April of 1942, Shinozaki had managed to re-open English, Tamil and Malay schools. Due to the war and differing opinions, China and Japan did not have cordial relations during that time. This contributed to the intentional delay of the opening of the Chinese schools during the Japanese occupation.

The second problem was the desire of the Japanese administration to incorporate the Japanese language, Nippon-go, into the schools. The Japanese were very keen to entrench the use of the Japanese language in its occupied territories. The objective of the Japanese in ensuring Nippon-go was adopted throughout the country was to infuse Nippon seishin or Japanese spirit into the people of Singapore. They were certain that with Nippon seishin, there would be unquestionable loyalty towards the Japanese Emperor. However, it was evident that if administrators were to adopt only Nippon-go during their day to day activities, businesses would cease as many locals were not well versed in the language. Therefore, lessons on the learning of Nippon-go commenced throughout the nation. Teachers were required to learn the language to have sufficient proficiency in the language before teaching the students. The teaching of Nippon-go became compulsory in schools from July 1942 and was successful despite the resentment of Singaporeans towards the Japanese. Pragmatic reasons, such as the Japanese emphasising the importance of Nippon-go in acquiring a job, contributed to its successful implementation.

The third problem was the limited access to suitable teaching materials such as textbooks. The Japanese administration was determined to ensure that the country was suitably entrenched in the Japanese culture. Therefore, it was important that textbooks used in schools
contained content aligned with the principles of the Japanese administration. There was limited access to the textbooks produced in Japan due to the wartime situation, therefore, existing texts were used but were thoroughly screened first to ensure an absence of undesirable content (Wilson, 1973).

4c. Science education

Despite the problems and the setbacks listed above, there were some significant improvements to the education system made during the Japanese occupation. Mechanical and engineering skills were promoted (Wilson, 1978) and there was a significant growth in the number of vocational schools. The schools received growing attendance from boys 14 years old and above and these students found employment as civilian mechanics with the Navy, Army, and Air Force. Within a year of conquering Singapore, the Japanese administration had set up six designated technical schools (Blackburn, 2017). Boys between 14 and 19 years of age were trained for the war-related jobs of aero-mechanics, mechanical engineers, electricians, mechanics, and technicians.

The development of these vocational schools stimulated the growth of the teaching of science in secondary schools in Singapore. It was evident that the commencement of the technical schools and trade schools produced the basis of the skilled labour force that played an important role in the economic progress of post-war Singapore (Wilson, 1973). The Japanese administration also changed the perspective and the mind-set of the residents of Singapore. The colonial administration was no longer seen as an impregnable force and it became evident that life in Singapore was possible without the protection of the colonial administration (Blackburn, 2017). The Japanese occupation was the beginning of the end of colonial rule and the beginning of the process of decolonization. There was a significant shift in educational policies after the Japanese occupation focusing more on the progress of the locals rather than retention of power for the ruling government as it was during the colonial administration.

When the British returned to Singapore after the Japanese occupation, the colonial administration was determined to conduct a more constructive form of governing by creating self-governing states (Blackburn, 2017). The description of the changes that took place during this pre-independence period is significant in understanding the beginnings of the teaching science in Singapore and the role education played in driving the economy during this time.

5a. Historical Background

Japan surrendered to the colonial administration on the 12th of September 1945. After the Japanese left Singapore, the British returned for a short period. Following the end of the Japanese occupation, there was an increase in national consciousness and a greater desire by the people of Singapore to manage their own affairs. Political groups such as the Malayan Democratic Union emerged signifying the growing unrest the people had for the colonial administration and an upsurge of nationalism in Singapore (Kim, 1973). It was imperative that the British looked into constitutional reform in Singapore to make way for greater local participation (Rendel, 1957).

The Malayan Planning Unit was set up to address the needs of Singapore after the Japanese occupation. The unit recognised that the war had changed the Singapore population and a lot more was desired by the locals (Blackburn & Hack, 2012). After many years, the colonial administration realised that the English language could provide the basis of common citizenship across the ethnic boundaries (Sai, 2013). This perspective had a significant impact on the education system during the pre-independence period as will be described.

On 1st July 1946, Singapore became a separate Crown Colony from the Straits Settlement, with its own Governor and Director of Education (Doraisamy et al., 1969). This meant that Singapore was governed according to its own legislation. With this move towards independence, the country saw more localisation of policies to suit Singapore’s specific needs (Chen & Koay, 2001). Singapore went through the nation’s first election in 1948. After the first election, two councils emerged, namely the legislative council and the executive council. The
legislative council comprised six local members elected through the first ever national election. The executive council, however, consisted entirely of colonial officials.

The Rendel Commission was introduced by Governor John Nicoll in July 1953 to undertake a comprehensive review of the constitution of the Singapore colony (Rendel, 1957). The commission paved the way for internal self-government while allowing the British to retain control over internal security and foreign affairs. Singapore achieved partial self-governance in 1955. Full internal self-government was obtained in 1958 with the People's Action Party forming the government.

5b. Structure of the education system

The post-war situation in Singapore posed two problems for the colonial administration. One was the rehabilitation of the school system and the second was building a new education system in preparation for self-governance in Singapore. The colonial administration in its assessment of the situation sought to solve these problems through the adoption of certain plans and policies such as the Ten Year Plan in 1947 (Gopinathan, 1974) and the All Party Committee Report in 1955 (Wilson, 1973). The policies were significant in the educational reforms that ensued.

An advisory council was set up in April 1946 and the then Director of Education, John Barrie Neilson presented the Ten Year Plan which was accepted on 7 August 1947. The Ten Year Plan was significant because it was seen as one of the first attempts to relate educational policies to clearly defined goals (Gopinathan, 1974). The key considerations during the programme were as follows –

1. Education should aim at fostering and extending the capacity for self-governance, and the ideals of civic loyalty and responsibility.
2. Equal educational opportunity was made available for all regardless of race and gender.
3. Understanding of basic skills to prepare students for higher learning.
4. Understanding cooperation and world relationships.
The first policy to follow the recommendations of the Ten Year Plan was the policy on free primary school education for all. For the first time in Singapore’s history, equal educational opportunities were offered regardless of race and gender (Gopinathan, 1974). There was a significant expansion of English language education from the Ten Year Programme and its 1950 successor, the Five Year Supplementary Plan (Blackburn, 2017). According to Gopinathan (1974), the extension of English medium education was aimed at fostering the capacity of self-government. This greatly reduced the racial conflict and tension that arose from the presence of the non-unified educational system during the colonial administration. The policy of free education expanded the teaching of science.

Vernacular schools still existed during this time, as it was determined that vernacular language was the best medium of instruction in schools. There was a second Ten Year Plan which is described in Chapter Six, in which the existence of vernacular education was again debated.

As mentioned previously, the Chinese medium schools were found to develop a political orientation different from those of Singapore’s colonial rulers and this was observed before World War Two. Grants-in-aid were introduced to control the type of curriculum taught in schools. However, this was not completely successful and the differences in ideologies continued to the pre-independence period. Therefore, the All Party Committee of the Legislative Assembly was formed in May 1955 with the objective of providing a comprehensive review of the Chinese medium schools in Singapore (Gopinathan, 1974) through the All Party Report. The appointment of the All Party Committee was significant to Singapore because it was the nation’s first attempt at a uniform approach to education. Even though the objective of the committee was to look into the Chinese medium schools, the resultant proposal was a policy of inclusion that met the needs of the different communities (Wilson, 1973). The representation of the members of the committee was diverse which allowed for the voices of all the communities to be heard. Gopinathan (1974) emphasised the importance of the All Party Report as the first true formation of Singapore’s national education policy.
In its final report released in February 1956 (Chew, 1956), numerous recommendations were highlighted. However, the underlying principles behind the recommendations can be summarised into three main points: the emphasis on unity through education; the improvement of language teaching; and the incorporation of civics and culture through education.

The first point is the emphasis on unity through education through the removal of discrimination against the vernacular schools and the consistent applications of the provisions across schools. The approach towards education was therefore consistent throughout the schools and a national education system was developed.

The second point was focused on language teaching. The committee noted that, while it recognised the significance of the mother tongue languages, vernacular schools should not ignore the importance of learning a common language. Bilingual education was recommended where the learning of the English language became compulsory. It was noted that opportunities for higher education and employment should be adjusted to account for students who have graduated from the vernacular schooling system in the past.

The third point was with regard to civics and culture. The report recommended that civics become a compulsory subject in all schools to ensure that values were incorporated into the education system. In this manner, it was also highlighted that all races and cultures should be respected and fostered including equal representation in textbooks used in schools.

In summary, the committee intended to build a nation, progressing towards independence, with different racial groups and cultural backgrounds and languages while ensuring that full educational opportunities were provided for all (Chew, 1956).

5c. Science education

As mentioned, a report on vocational and technical education by H. R. Cheeseman (1938) recommended an increased exposure of science in the curriculum in English medium schools. Therefore, during the pre-independence period, there was an increased emphasis on the teaching of science. More schools were offering science subjects. Logistical arrangements were
made by schools to ensure that there were textbooks and facilities that would aid in the teaching of science. The pre-independence period saw the beginnings of a standard set of science textbooks used in the secondary school classroom. There was also a significant attempt by the colonial administration to increase the number of science laboratories in secondary schools.

Further steady progress was made during this period in implementing the policy of the Department of Education regarding science teaching in secondary schools (Ho, 1952). In 1948 there were 40 government and aided English schools teaching science to 204 science classes comprising 6,672 students. Considerable progress was made with the introduction and extension of science teaching in English schools and vernacular schools. In 1955, there was a change in educational structure with the establishment of the primary school, secondary school, and post-secondary school system, as mentioned in Chapter Two. With this change, science was taught in all primary schools and physics, chemistry and biology were introduced at the upper secondary levels (Goh, Diong & Yeo, 1989). This was noted to be the first introduction of the teaching of biology at the secondary school level in Singapore. Further development of the teaching of biology is described in Chapter Six. However, as will also be described in Chapter Six, the sudden increase in the number of schools and in the enrolment of students, led to several problems, including the teachers’ competencies in science teaching.

From 1942 to 1959 vocational and technical education increased in emphasis and this supported the industrialization of the Singapore economy. A polytechnic was established to address the technical labour shortage of the 1950s that came with the growth of manufacturing (Blackburn, 2017). The establishment of these educational institutions was an attempt by the colonial administration to decolonise Singapore by creating a foundation of industrial training that would allow the country to supplement its workforce for an industrialised independent nation. There was significant progress in the teaching of science in Singapore during this time. The foundation of science teaching built by the colonial administration after the war was significant in ensuring a further and steady growth of the teaching of science and biology during the independence stage which will be described in Chapter Six.
This chapter has outlined the evolution of the education system in Singapore given its changing circumstances from colonialized nation to independence with special reference to the teaching of science. It brings to light the foundations of the Singapore education system today. The political and economic perspectives that influenced the foundations of the education system in the 20th century are significant to the foundations of the education system today. This chapter also outlined the progression of the teaching of science in Singapore, from one which was strictly controlled to one that received greater emphasis and was made more widely available through the introduction of vocational and technical education. Biology, being a specialised subject within science, was only introduced after a significant foundation was developed in the area of science education. Based on the literature reviewed, the teaching of biology was made widely available only after 1958 (Tan, 2012).

The next chapter describes the recent developments in the teaching of science in secondary schools in Singapore, with special reference to the teaching of biology where applicable.
CHAPTER SIX

RECENT DEVELOPMENTS

1. Introduction

This chapter addresses the second aim of the study, which is to develop an understanding of the recent developments in the teaching of science in secondary schools in Singapore from 1959 to recent times, with special reference to the teaching of biology. The teaching of science in Singapore has been shaped by historical, political and societal forces (Tan, Lim & Poon, 2014). Singapore’s problems as a developing country were compounded by its multi-racial population as described in Chapter Five. Singapore’s founding fathers, namely Lee Kuan Yew, Goh Keng Swee, and S. Rajaratnam implemented several important educational policies to steadily and slowly build a united, multi-racial nation (Gopinathan, Deng, Lee, 2013). As the economic landscape evolved into one more focused on manufacturing, the emphasis on the teaching of science and biology in Singapore secondary schools increased.

As mentioned in Chapter Five, the teaching of science received more significance during the pre-independence period. Biology, however, appeared to receive emphasis only after a foundation was developed in the area of science education. Therefore, one of the challenges faced in writing this chapter was the limited publications that illustrated the state of the teaching of biology in secondary schools in Singapore during the earlier years before independence.

Evidence used for this chapter was pieced together from reviewing publications, speeches and public documents from the Ministry of Education. Singapore went through three different phases in its education landscape from 1959 to 2011. These three phases were, the survival-driven phase (1959 – 1978), the efficiency-driven phase (1979 – 1996) and the ability driven phase (1997 – 2011) and they are used to organise this chapter. There are three sections within each phase: firstly, there is a discussion of the state of governance in Singapore and the changing economic landscape at that time; secondly the educational policies are described; and thirdly the impact of these policies on the teaching of science and biology in secondary schools in Singapore will also be discussed. Figure 6.1 illustrates the outline of this chapter.
Science culture refers to the attitudes of the public towards science and their general understanding of it (Solomon, 1996). These attitudes require systems and frameworks to be in place before they are formed. A science culture was relatively non-existent in Singapore before the 1950s (Tan, Lim & Phua, 2017). There are three main reasons researchers have attributed to this absence of a science culture in Singapore.

Firstly, Singapore’s immediate emphasis upon its founding in 1819 was on trade and commerce and there was relatively little emphasis on science and technology as explained previously in Chapter Five. There was no necessity to incorporate science and technology into the education system nor the need to explore an additional avenue for socio-economic development during the colonial administration as the nation’s economy was thriving in trade. Therefore the success of the country in trade and commerce as a result of its strategic location contributed to the lack of emphasis on science and technology (Tan, Lim & Phua, 2017).

Secondly, the political instability in Singapore leading to independence contributed to the delay in the emphasis on the teaching of science and therefore a delay in the introduction of a science culture in Singapore. Singapore’s governing bodies spent a significant amount of time on nation-building and the building of a cohesive multi-racial society through the educational
policies implemented. Less time was spent on the development of science teaching in secondary schools (Tan, Lim & Phua, 2017).

Thirdly, Singapore struggled to produce scientists of international repute who could drive the establishment of an educational institution focused on science during the pre-independence period (Tan, Lim & Phua, 2017). It was only after independence that the government of Singapore identified different vehicles to drive the socio-economic success of the country besides trade and commerce. This was when the teaching of science was observed to increase in importance.

3. The survival driven phase (1959 – 1978)

This period was seen as the important years of educational developments in Singapore (Doraisamy et al., 1969) and was labelled as the survival-driven phase because the educational reforms made were essential in setting the building blocks for the survival of a united sovereign nation. With the increasing competition from other Asian countries for low-skilled labour, there was a growing realisation that Singapore’s comparative advantage was eroding and a higher-skilled economy was needed. According to Gopinathan (1974), the education of Singapore’s youth was considered significant in transforming the diversified state of the nation. Therefore, in response to the changing economic landscape, the government implemented policies to ensure the education system evolved. Science and technology became increasingly important to Singapore to compete as a viable economic entity and break away from the dependency on entrepot trade (Gopinathan, 2013). Therefore, the main focus of this period was on expanding basic education as effectively and efficiently as possible. Schools were built rapidly and teachers were recruited on a large scale and the teaching of science became increasingly important.
3a. State of governance

There were significant political events that occurred during this phase that defined the government’s directions with respect to education. First was the merger with Malaysia in 1963. Within two years, the two nations separated which led to Singapore’s independence in 1965. The following section briefly notes events occurring before the merger, during and after the merger which is of significance to the educational policies adopted by Singapore as an independent nation.

Before the merger, the first general election was held in April 1959 and the People’s Action Party (PAP), a local democratic political party led by Lee Kuan Yew, came into power. Lee Kuan Yew understood the desperate need for national unity and saw an avenue in establishing this through education.

What is in the balance is the very foundation of our society. For if we are not to perish in the chaos caused by antagonisms and prejudices between watertight cultural and linguistic compartments, then you have to educate the right responses amongst our young people in schools (Gopinathan, 2013 p. 89).

Lee Kuan Yew placed a significant emphasis on the role of education in the building of a multi-racial nation. The People’s Action Party believed that Singapore would achieve greater economic success if a merger with Malaysia took place because Singapore’s economy was still dependent on trade at this time. The merger allowed Singapore to take advantage of the wide hinterland trade market to the north of Singapore (Gopinathan, 2013).

Singapore merged with Malaysia on 16 September 1963 and with the merger, came the end of colonialism in Singapore and the beginning of the Federation of Malaya. Despite uniformity on the grounds of the legislature and general management of the two nations, Singapore maintained its autonomy in education and labour (Gopinathan, 1974). During the merger, important issues surfaced on the implications of the presence of vernacular schools. As mentioned in Chapter Five, vernacular schools used their respective mother tongue languages as the language medium for the teaching of all subjects. The People’s Action Party intended to
remove the vernacular system to ensure fewer inconsistencies and inequalities in the education system (Ong, 1964). However, the proposed removal of the vernacular schools was a disputed issue between Singapore and Malaysia.

There were numerous contradictions and disagreements with legislature and management between Singapore and Malaysia, including those related to education. Therefore, in 1965, Singapore and Malaysia declared independence as two individual nations. This signified an opportunity for Singapore to legislate a more customised national education policy that could ease the rising racial tensions that arose during the merger (Ong, 1964).

The separation also forced Singapore to explore alternate avenues for economic development such as manufacturing. The evolution of the economic landscape led to the introduction of key educational policies which eventually contributed to the changing educational landscape in Singapore (Chen & Koay, 2001). The following section highlights the educational policies that were significant during the early independence years. In summary, after the separation, Singapore faced two big issues - rising racial tensions; and a changing economic landscape. The educational policies from 1959 to 1978, therefore, focused on managing these two issues.

3b. Educational policies

During the late 1950s, 70% of Singapore’s gross domestic product was derived from entrepot trade (Gopinathan, 2013). The small manufacturing sector consisted mainly of light engineering, assembly of vehicles and marine engineering. Manufacturing development was observed to stagnate at about 12% of gross domestic production (Gopinathan, 2013) and the government focused on the need to expand the industrial base through education.

The educational policies in 1959 had four main aims to address the two issues stated. The first aim was to increase emphasis on the study of science, mathematics and technical education. The second aim was to ensure there was equal treatment for the four language streams, namely the Malay, Chinese, Tamil, and English. The third aim was to establish four
official languages with the Malay language as the national language. And the last aim was to build loyalty towards the nation of Singapore.

There were four policies that were introduced in support of these four main aims and were significant to the teaching of science and biology in secondary schools in Singapore. These four policies are listed below and are described in turn. Each of these educational policies worked together to achieve the four aims stated above.

i. Emphasis on science, mathematics and technical education
ii. Equal treatment for all streams
iii. Emphasis on bilingualism
iv. Retention and promotion

i. **Emphasis on science, mathematics and technical education.**

From self-governance in 1959 through the early years of post-independence, one of the main priorities of the government was to build up its economy through industrialisation (Goh & Gopinathan, 2008). Industrialisation was seen as a viable option by the government to meet the challenges of high unemployment coupled with a rapidly growing population (Chua, 2010). Based on the education-economy relationship, science, and technical education, therefore, became an area of focus (Bhathal, 1982: Chua, 2010) to drive the changing economic landscape. The focus on science and technology has remained a key cornerstone of Singapore’s education and economic strategy to present times (Tan, Lim & Poon, 2014). Science first became part of the formal primary school curriculum in 1959 (Yeow, 1982). The objectives of teaching science (Yeow, 1982, p.160) during this time were the following –

- To create an interest in nature and its working
- To encourage the natural curiosity of children and to inculcate a spirit of inquiry
- To train the children to observe, to experiment and to seek further knowledge

By 1968, science and mathematics were taught in English in most secondary schools. This was a significant improvement from the inconsistent teaching of science during the colonial period. After the 1968 general elections, Toh Chin Chye was appointed Singapore’s
first minister for science and technology. He played a significant role in advancing the landscape of science and technology in Singapore. There was an increase in graduate-level research in the area of science and technology during the 1960s (Tan, Lim & Poon, 2014).

The teaching of biology increased in significance during this period. As mentioned earlier, the biology curriculum during this period was changing. Biology in the 1950s consisted mainly of a study of life from a descriptive approach. Emphasis was placed on the acquisition of facts and the information that biologists have obtained. Examples of this would be the study of the morphology, anatomy, and physiology of a flowering plant and vertebrates. In the 1960s, biology teaching shifted to experimentation and discovery approaches. The objective was to instil in the students the method of scientific inquiry and critical and analytical thinking. The syllabus included a study of life processes and interdependence of living organisms. In the 1990s, the biology curriculum focused on life processes. The emphasis was on the relationships of man with the environment and other organisms. For example, on the topic of gaseous exchange, an emphasis was placed on the disorders of the lungs and its links with smoking. Microorganisms are studied in terms of their impact on the lifestyle of man, such as in the brewing of wine and baking of bread. In the 2000s, life sciences were incorporated into the curriculum with an emphasis on molecular biology. More emphasis was placed on the concept of genetics and Deoxyribonucleic Acid (DNA).

As noted, a change in examination format was also observed. In the 1950s, only essay questions were set and the students had a choice of answering four out of five questions. However, during the 1970s, fewer questions focused on description and instead focused on explanation. Questions were also divided into several parts. Multiple choice questions and structured questions were also introduced during this time. Currently, more data-based questions are introduced in which students are expected to analyse the data provided and establish links between their content knowledge and the data provided. The objective of the change in assessment structure is to promote higher order thinking and to draw away from rote learning.
By the 1960s, biology was taught in Singapore schools at four levels:

- Primary school science from Primary Three to Primary Six;
- Lower secondary science in Secondary One and Two;
- Upper secondary as an elective subject;
- Post-secondary institutions as a GCE ‘A’ level subject.

Science at the first two levels is taken by all students. At the upper secondary levels, biology is offered as an elective in which it is offered either as a single subject or an integrated subject option, Science (Chemistry with Biology or Physics with Biology). This structure has continued until today.

Other committees, councils, and associations were also established during this time that signified the shift of the importance of the teaching of science and biology in Singapore. A science culture developed through the establishment of these committees and councils. A key aspect of the science culture movement that was observed by Tan and Subramaniam (2009) was the inclusion of science education teachers in its movement.

The Science Teachers Association of Singapore was set up in 1965 by a group of enthusiastic science teachers. The association worked closely with the Institute of Education in improving the quality of science teaching in Singapore (Tan, Lim & Poon, 2014) and also introduced the first competitive Science Fair in 1969 (Bhathal, 1982).

The Science Council of Singapore was first established in 1967 in an effort to drive governmental policies on science and technology. The Science Council introduced the Science Quiz which was televised nationwide in 1972 (Bhathal, 1982). This was significant in popularising the learning of science. The Science Council adapted over the years into the Agency for Science, Technology, and Research (A*STAR) which was established in 2001 (Tan, Lim & Poon, 2014).

The Singapore Institute of Biology was founded in 1974 by a group of enthusiastic biologists who wanted to further the cause of biology and its application (Tan, Wee,
Subramaniam, 2017). One of the objectives of the Institute was to encourage the improvement of the teaching of biology. The Singapore Institute of Biology was one of the first institutes in Singapore that catered specifically to the extended learning of biology. This marked a pivotal shift in the importance of biology as a science subject in Singapore. Biology was to become one of the cornerstones of Singapore’s economy through the introduction of life sciences, as will be mentioned later in the section on the ability driven phase. Following the establishment of the Singapore Institute of Biology, there were also several societies established in the biology field such as the Singapore Society for Microbiology and Biotechnology in 1983.

Towards the end of the survival-driven phase, the Singapore National Academy of Science was established in 1976. Its principal objective was the promotion of science and technology. It behaved as an umbrella organisation which represented the various scientific societies in Singapore. The establishment of the Singapore National Academy of Science was an important aspect of the emerging science culture in Singapore. It represented an important shift of attitude towards science as a possible vehicle to drive Singapore’s socio-economic development and therefore an increasingly important position in the education system.

In addition, a Ministry of Science and Technology was established in April 1968. Although the establishment of this ministry signified a shift in the attitudes of the government towards the teaching of science, it was dissolved in 1981 due to limited funding. According to the then Prime Minister Goh Chok Tong (Gopinathan, 2013), research and development were not seen as critical to the economic growth of Singapore during the 1960s. It was only in 1991 that a research and development policy was implemented. The government did recognise the backwardness in the development of science and technology in Singapore. In the 1980s, the government introduced developmental strategies to improve the economy through science and technology (Goh & Gopinathan, 2008). This was observed during the efficiency-driven phase.
ii. **Equal treatment for all streams.**

In an effort to ensure equality, assessments across all streams at both primary and secondary levels were standardised. In 1960, the Primary School Leaving Examination was first instituted in all schools. Subsequently, in 1962 secondary level assessment was also standardised to ensure equal status for all students (Chua, 2010). In 1965, common questions for science and mathematics were set for the Primary School Leaving Examination which signified a standardisation of assessment in the area of science and mathematics. In 1970, there was an important integration of the examination system with the introduction of the Singapore Cambridge General Certificate of Education. All students, regardless of the stream and the school, sat for a common examination. This was an important move towards ensuring all schools, regardless of language medium, followed a consistent and standardised form of assessment. The competency of the knowledge of science in the students was standardised with the equal treatment of all streams.

iii. **Emphasis on bilingualism**

The bilingual policy was of specific significance to Singapore’s education system because it allowed the nation to preserve and respect its racial diversity but at the same time ensure its people were educated in English. In 1966, in an effort to break down linguistic barriers and the inequalities of occupational opportunities, it became compulsory for all students to undertake English as a second language (Chua, 2010). It was offered as an examinable subject at School Certificate level in 1969. The government merged many schools in 1969 in an effort to ensure that the English language was more widely used, resulting in the introduction of integrated schools (Goh, 1978). Integrated schools were schools that used both English and mother tongue language as the media for instruction. In the same year, the Cabinet decided that English would be recognised as Singapore’s common language. During this period, science was taught mainly in the English language. This educational policy on bilingualism allowed standardisation of the teaching of the English language throughout schools in Singapore. This
resulted in more schools offering science as a secondary school subject. The teaching of science became more widely available to students enrolled in secondary schools.

iv. **Retention and Promotion.**

In 1959, automatic promotion for students was replaced by a system whereby up to ten percent of the students in each grade could be retained (Goh, 1978). This allowed weaker students an additional year to master their content of the subjects taught. However, it was noted that some students were still advanced without much consideration and this resulted in the insufficient acquisition of foundation content before promotion. Students who were advanced suffered from a lack of foundation of science and this affected the quality of science graduates. The attrition rates began to increase due to the students’ inability to cope (Goh, 1978). The problems of the rising attrition rate are addressed later in this section.

**3c. Impact of the educational policies**

Despite a clear and comprehensive approach to education during the survival-driven phase, there were numerous problems that arose during this time. In 1978, Dr. Goh Keng Swee, the then Deputy Prime Minister, led a study team to identify these problems (Yap et al., 2008). There were five main problems highlighted by Dr. Goh and his team in the Goh Keng Swee report and these are listed below. The problems stated were not all directly relevant to the development of science and biology teaching in Singapore. However, a brief description of each of these problems aims to provide a complete understanding of the state of the education system during the survival-driven phase. These problems are listed below and described briefly.

i. Education wastage

ii. Low literacy

iii. Ineffective bilingualism

iv. Variation in schools’ performance

v. Morale of teachers
i. **Education wastage.**

In the Goh Keng Swee report, a comparison was made with affluent nations like the United Kingdom and Japan on methods of managing the attrition rate in schools. The high attrition rate in Singapore was attributed to the struggle the students faced in coping with the bilingual policy introduced during the survival-driven phase as well as the inability to cope with the rigour and the content of the other subjects. As mentioned earlier, one of the policies implemented during the survival-driven phase was the retention and promotion policy. This may have led to students being promoted even though the accurate acquisition of required content had not been fulfilled. Without a proper streaming process, a loosely adhered to retention policy as well as an enforced bilingual policy, students began dropping out of school.

ii. **Low literacy.**

In 1975, the Ministry of Education conducted two surveys on students’ literacy levels. The findings showed that at least 33 percent of the primary six populations in the English stream and 25 percent in the Chinese stream did not meet the minimum literacy levels (Goh, 1978). The low literacy levels were attributed to the high attrition rates in the schools. Students were dropping out of school before attaining the required level of literacy. The low level of literacy also meant that there was a low level of understanding of science.

iii. **Ineffective bilingualism**

The introduction of bilingualism in the schools saw numerous problems that were a result of a lack of foresight (Goh, 1978). The policy saw rejection in the vernacular schools which argued that it would put a strain on the students who were not of high language abilities. The teachers were insufficiently trained in delivering the subjects in the English language.

iv. **Variation in schools’ performance.**

In 1978, the academic performance of some schools was consistently better than others. There were two main reasons cited in the Goh Keng Swee report (Goh, 1978) - the different home backgrounds of the students; and the inconsistent qualifications of the teachers.
v. Morale of teachers.

With the rapid expansion of schools in the 1970s to cater to a growing student population, there was mass recruitment of teachers (Gopinathan, Wong, & Tang, 2008). There was such a severe shortage of teachers that the teachers in training had to undertake part-time teaching responsibilities in schools. During the Commission of Inquiry into Education, conducted in 1963 (Lim, 1964), it was reported that science teachers were discontented with the science curriculum. Some felt that the curriculum was too broad and it was impossible to complete. Others felt that there was too much emphasis on the assessment and too little emphasis on the essence of science which is to ignite the inquisitive and curious nature of the students.

The teachers also expressed a lack of confidence in their own competencies and content knowledge of science. It was reported that there were insufficiently trained science teachers and in fact, a large number of science teachers had neither science background nor science training (Yeow, 1982). The teachers, therefore, felt discouraged and incompetent to teach science. The lack of training had a direct impact on the morale of the teachers. This also had an impact on the manner in which the science content was delivered to the students.

The science lessons consist mainly of exposition of factual information through the talk and chalk method. Little is done to provide pupils with a variety of experiences through active involvement in conducting experiments and investigations which lead to the acquisition of the basic process skills and relevant concepts (Yeow, 1982, p.163).

The 1963 report mentioned above also reported that science teaching consisted of verbal dictation of notes by the teachers. There was also a lack of equipment and facilities that led to the students having limited exposure to laboratory activities. This was a result of the lack of competency of the science teachers. The teachers were not confident in their mastery of the subject and therefore were observed to discourage questions and discussions (Yeow, 1982). The majority of the science lessons were conducted in a teacher centred manner in which factual information was simply memorised by the students. There was a lack of inquiry and active
involvement of the students in conducting experiments and investigations, which were necessary for the acquisition of the basic process skills and relevant concepts (Yeow, 1982).

The Ministry of Education responded to the lack of competency of the teachers by establishing the Institute of Education in 1973. This signified the beginning of specialised training in the teaching of science (Stewart, 2010). The progress and development of the Institute of Education will be described in the next section.


4a. State of governance

The efficiency-driven phase allowed the government more time to fine-tune the education system to address some of the problems highlighted in the previous section. The focus was more pragmatic and more attention was placed on looking forward in terms of policies and programmes. During this phase of education, the focus shifted to one that created more pathways and opportunities for the students in order to reduce the high attrition rate and to improve quality of teaching and learning in science and biology.

Regional competition in traditional manufacturing and services sector intensified during the 1970s and Singapore recognised the need to broaden and diversify its economic base. There was a need to transform into a knowledge-based economy (Tan, Lim & Phua, 2017) from a labour intensive economy. Therefore, Singapore began exploring the research and development sector. In 1985, a research and development group was set up within the Institute of Systems Science to drive applied research programmes (Tan, Lim & Phua, 2017). Research and development became a cornerstone in developing a knowledge-based economy. The focus on research and development in the area of science signified an important shift in the relevance of the teaching of science and biology. There was a need to ensure the development of competent science and biology teachers and a structured curriculum in secondary schools to support the teaching and learning of science and biology.
To support the drive towards sustainable development and reflecting the economic restructuring strategies, a revised education system was introduced in 1978 to address some of the problems highlighted during the survival-driven phase (Gopinathan, 2013).

4b. Educational policies

There were several recommendations from the Goh Keng Swee report which played a significant role in determining the educational policies adopted during the efficiency-driven phase. Some of these educational policies, although not explicitly related to the teaching of science and biology, provided an insight into the educational system during this time and an understanding of the increasing relevance of the teaching of science and biology.

The key features of the efficiency-driven education system were a national curriculum with an emphasis on the following items –

i. Improvement in curriculum development;

ii. Bilingualism;

iii. Regulation of assessments;

iv. Improvement in the teaching of science and biology.

i. Improvement in curriculum development.

The Curriculum Development Institute of Singapore was established in 1980 to manage curriculum development. The curriculum development process was also altered to take into account the concerns of teachers and students when deciding and implementing a new curriculum.

While top-down initiation of curriculum changes has been relevant and useful, insufficient feedback from the ground level means that the top management has to depend on first principles, personal initiative and whatever appreciation of the ground level they could gather from informal channels (Goh, 1978, pg.78).

As mentioned earlier, the morale of the teachers was affected by the lack of communication between the ministry and the teachers. With the establishment of the
Curriculum Development Institute, teachers were involved in the curriculum development process and this allowed them to develop ownership and commitment in executing the curriculum more effectively (Gopinathan, 2013).

ii. Bilingualism

Bilingualism was highlighted as one of the problems during the survival-driven phase. One of the contributing factors was the insufficient training of the teachers and their resultant lack of competency. This was also observed in the area of the teaching of science and biology. Therefore, there was an increase in emphasis on the importance of teacher training and education to develop language and content proficiency (Chen & Koay, 2001). Teacher training processes were improved and language instruction was also included as part of the training at the Teachers’ Training College.

iii. Regulation of assessments.

As mentioned in Chapter Two, there are three streams in Singapore government schools - express, which is the most demanding stream; normal academic; and normal technical which is the less demanding stream. Through the regulation of assessments by the Ministry of Education, students were able to be placed in streams that suited their abilities (Goh, 1978). It was also suggested that streaming occurs after three to four years. The introduction of lateral movement across streams was also recommended to correctly stream students into the most appropriate stream. After their primary school education, students were placed in the appropriate secondary school courses that would match their learning pace and ability (Gopinathan, 2013). This resulted in an increase in the number of students progressing to post-secondary vocational and technical education and fewer students dropping out of school.

iv. Improvement in the teaching of science and biology.

The Singapore government recognised that a sustainable supply of local scientists and engineers was needed to transform Singapore into a technologically advanced city-state (Gopinathan, 2013). It was, therefore, important to evaluate and improve the teaching of science
including biology at the secondary level to produce a significant number of science graduates. There were two aspects that the Ministry of Education focused on to improve the teaching of science - improvement of logistical support; and teacher training.

The logistical support provided by the Ministry of Education was in the form of teaching materials and physical space. The Curriculum Development Institute of Singapore brought teachers together to author certain books and materials that were aligned with the inquiry approach for science (Cahill, 1984). The curricular focus of the teaching of science and biology at the lower secondary level was on the development of ‘inquiring minds’ (Tan, 1989, p.64). Therefore there were expectations for a more versatile delivery of science lessons. However, as observed during the survival-driven phase, the delivery of science lessons was found to be teacher centred. This was assumed to be the result of the lack of confidence and competencies of the science teachers. As mentioned, many of the science teachers did not have an educational background in science. This was addressed by the improvement of teacher training which is described later.

Textbooks and materials were standardised to address the effectiveness of science teaching (Gopinathan & Chong, 2008). This means that even without proper training or workshops, the teachers would be able to implement the teaching of science content simply by following the materials provided (Tan, 1989).

The Ministry of Education ensured science was taught through experimental and laboratory activities by introducing physical structures and spaces. According to Cahill (1984), 60% of primary schools had a science garden to support the learning of plant biology. This provided a physical space for teachers to explore more inquiry-based lessons and investigations. This reflected a significant emphasis on the teaching of biology. More science laboratories were built in schools to support the learning and assessment of science (Tan, Lim & Poon, 2014). This was to reflect the importance of experimentation and investigations on the teaching and learning of science. Science practical assessment was included as part of the national examinations and elements of laboratory activities were assessed in the theory papers. The
In 1960, the Teachers’ Training College included the training of university graduates as secondary school teachers. In June 1960, training at the Teachers’ Training College was made compulsory for all new non-graduate and untrained teachers who had taken up teaching in Singapore on or after 1 January 1959 (Wong & Gwee, 1972). Teachers who were recruited before 1 January 1959 were also encouraged to apply for training at the college. This signified a concerted effort by the government to increase the competency of the teachers.

By 1973, the predecessor of the National Institute of Education (NIE), the Institute of Education (IE) was formed and specialized training of science teacher became possible (Steward, 2010). Currently, teacher education training at the NIE is compulsory for all pre-service teachers. The NIE has the expertise to develop teachers in all disciplines of study, including sciences and biology. Science teacher education is conceptualized as a continuum from the education of pre-service teachers to the continuing professional development of in-service science teachers (Tan, 2018). There are two main routes for pre-service teachers at the National Institute of Education. The first is the Post-Graduate Diploma in Education (PGDE) which is a 16-month program for prospective graduate teachers who already have had a first degree in a science related field. The second type of program is the four-year Bachelor of Science (Education) (BSc(Ed)) which is targeted at prospective teachers who are non-graduates.

According to Tan (2018), there are differences in the teaching of biology, chemistry, and physics. However, the key ideas of assessment, nature of science, science laboratory work, conceptual understanding and key strategies (such as questioning, scientific argumentation, flip classrooms etc.) in all of the different sub-disciplines are addressed at the NIE. To prepare the pre-service teachers for teaching practice, a microteaching component is included in all the curriculum courses. Pre-service teachers in the PGDE program have one four week observation in school and a ten-week practicum in schools at the end of their course. Pre-service teachers in
the degree program have a one-week observation in schools in year two of their course, a five-week practicum in year three and a ten-week final practicum in year four.

During their school practicum, pre-service teachers are mentored by a senior teacher in school as well as a supervisor from NIE. In this partnership, the pre-service teacher, their school mentor, and the NIE supervisor develop a better understanding of the teaching and learning process of a teacher and also of students in learning science in school (Tan, 2018).

As Tan (2018) notes, scientific knowledge is constantly changing and science teachers need to keep abreast with the changing content knowledge. Professional development courses and programs at NIE are offered to in-service teachers to ensure constant upgrading of content knowledge. These courses are designed in consultation with the Ministry of Education to ensure the relevance of professional development opportunities.

4c. Impact of the educational policies

The impact of all these policies saw a shift in the science culture in Singapore and this can be seen through the introduction of numerous science programmes and competitions. Significant programmes were launched during the efficiency-driven phase such as the Young Scientist Badge in 1982. Students could earn these badges by performing various simple investigations in different field such as ecology and zoology (Tan, Lim & Poon, 2014). Biology was receiving an increasing amount of emphasis on education. Science research programmes were also started for older students which allowed them the opportunities to meet scientists (Bhathal, 1982). There were also numerous overseas science attachment programmes and students were given the opportunity to compete on numerous platforms in international science competitions. As mentioned earlier, one of the problems faced during this phase was the morale of the teachers which was affected by their perceived incompetency in teaching the science curriculum. The results of this competition provided them with a morale boost to continue striving towards the next phase. The competition was also an affirmation of the approach adopted by the Ministry of Education towards science and biology teaching. This was also an effort to entice young Singaporeans to take up science disciplines in the universities
This concerted effort resulted in an increase in the output of science graduates during the late 1980s.

In 1995, Singapore participated in a competition known as the Trends in International Mathematics and Science Study. It involved 41 countries and Singapore students, aged 14 years old, ranked first in the Secondary Two science tests. The international average was 500 and Singapore scored 643, above South Korea, Japan, and Hong Kong. It was noted by Goh & Gopinathan (2008) that the policy of streaming students according to their academic abilities allowed the teachers to focus on their teaching of science. The students also appeared to have benefitted from the improvements in curriculum introduced in 1980.

5. The ability driven phase (1997 – 2011)

5a. State of governance

During the late 1990s, as globalisation and technological advancements hastened the progress of other countries, Singapore struggled to remain competitive in an ever-changing economic landscape (Gopinathan, 2013). The Singapore government ascertained that it was necessary to shift towards a knowledge-based economy in which skills and knowledge were required. This initiative aimed to equip and prepare students to meet the challenges in a knowledge economy by taking into consideration their individual abilities and talents, rather than the sole reliance on examination grades (Tan, Chow & Goh, 2008). The initiative also represented a paradigm shift from the efficiency-driven phase. The efficiency-driven phase focused on producing skilled workers for the economy, whereas the ability driven phase focused on identifying and developing the talents and abilities of students. Former Senior Minister of State for Education, Peter Chen, emphasised the need for an education system in a knowledge economy to provide a balanced and well-rounded education that would develop every individual in the most appropriate manner such that his or her full potential can be realised (Tan, Chow & Goh, 2008).

In 2010, many Asian companies chose Singapore as a base for the globalisation of their products and services. The continued growth of the gross domestic product due to the
anchoring of several multi-national companies in Singapore created jobs for Singaporeans and allowed Singapore to position the economy for the future. Through the expanding economy, Singapore’s education system had to move in tandem with educational transformations that would produce the appropriately skilled workforce.

Educational transformations were essential at the secondary and primary school level. The transformation started with the introduction of the Thinking Schools Learning Nation vision which had a significant impact on the teaching of science and biology. This section starts with the description of the Thinking Schools Learning Station vision followed by the impact the vision had on the teaching of science and biology.

5b. Educational policies

In 1997, the then Prime Minister, Goh Chok Tong spoke about the need for schools to prepare students to meet the challenges of a rapidly changing world in the 21st century. He summed up this vision for schools as Thinking Schools, Learning Nation. This vision involved giving the opportunity to students and teachers to challenge assumptions and explore better ways to do things through participation, creativity, and innovation. The curriculum was revamped to allow more time for the introduction of thinking skills and the use of Information and Communication Technology (Gopinathan & Chong, 2008).

With this vision, schools were expected to move away from an education delivery that emphasised academic results to one that would be balanced and holistic. With increased autonomy given to schools to manage education delivery, there was a need for schools themselves to take ownership of the drive for education improvement and growth. However, for all this to happen, it was important to change the way students were assessed (Seah & Ow, 2003).

After the unveiling of the vision, many important educational initiatives were introduced. These initiatives which have had a direct impact on science teachers’ classroom practices, namely the Teach Less, Learn More initiative and the Information Technology (IT) Masterplan are described below.
The *Teach Less, Learn More* initiative was introduced in 2004 by the Prime Minister of Singapore, Lee Hsien Loong during his National Day speech to the nation. The initiative was intended to promote more engaged learning, high-quality teaching and innovative and effective instructional approaches (Ministry of Education of Singapore, 2006). As described by the then education minister, Tharman Shanmugaratnam, the intention of the initiative is to encourage teachers to engage students in a more innovative and effective manner, rather than to teach for tests and examinations (Tan, 2012).

Through this initiative, teachers were strongly encouraged to adopt pedagogical approaches that were progressive and innovative. Teachers were also encouraged to refrain from the drill and practice approach in which emphasis is placed on grades. It was also envisioned that the Teach Less, Learn More initiative would produce innovative and thinking students who would support the growth of the knowledge-based economy.

The IT Master Plan involved improving students’ information literacy which became an important aspect of students’ learning. It refers to the ability of students to analyse and use information provided to them (Mokhtar, 2005). Resource-based learning in which printed materials are used for the purpose of teaching and learning has been in use in schools for a long time. Singapore government schools are heavily reliant on resource-based learning and therefore there is a strong dependence on resources in the area of textbooks, workbooks, and practical books. In 2009, a Teacher Education Model for the 21st century was released by the National Institute of Education. The National Institute of Education proposed skill sets for students, comprising information literacy, media literacy and Information, and Communication Technology (ICT) literacy. The model highlighted a concerted effort to move away from the dependence on books and instead onto the development of media and ICT literacy.

The shift towards implementation of ICT in the classroom with the introduction of the IT Master Plan in 1997 was a welcome and necessary change required to change the dynamics of the classroom. ICT related courses became a pre-requisite for pre-service teachers as well as in-service teachers.
5c. Impact of the educational policies

Curriculum review.

The science curriculum was reduced to free up curricular time for thinking skills and the use of ICT. It was also adjusted to reflect new developments in science and technology (Tan, Lim & Poon, 2014) and there was an emphasis on life sciences. Life sciences or biological sciences comprise the branches of science that involve the scientific study of life and organisms, such as microorganisms, plants, and animals including human beings as well as an extended aspect on molecular biology. Molecular biology encompassed the learning of DNA (Deoxyribonucleic Acid) and genetics. Singapore identified life sciences as a new engine for economic growth (Tan, 2015) and this was manifested in the emphasis on life sciences in secondary school curriculum and universities as part of the nation’s strategic move towards a knowledge-based economy.

In the year 2000, there was a greater emphasis on molecular biology as well, in the secondary school biology curriculum (Tan, 2015). Schools were also provided with more funding to support this review of curriculum. A DNA (Deoxyribonucleic Acid) centre was set up at the National Institute of Education in 2003 to provide teachers and students with hands-on experience of investigations or practicals in the area of life sciences (Teo, 2003). A similar DNA Learning Lab was set up at the Singapore Science Centre in 2003 to make the knowledge of life sciences accessible to younger students and to the public. The impact of these initiatives is described in Chapter Seven.

Inquiry-Based learning.

In addition to the introduction of life sciences, there was a shift in the teaching and learning of science into an inquiry-based approach. The objective was to create a nation of thinking and committed citizens who are able to face the challenges of the future (Tan, Lim, & Poon, 2014) as well as to develop students as active learners rather than passive recipients of knowledge. The science curriculum in Singapore secondary schools started focusing on the inquiry approach in 2008 (Tan, 2015). The ‘Five E’ model developed by the Biological
Sciences Curriculum Study is used to support the inquiry approach through lesson planning and implementation. This model includes five stages in the teaching and learning process, namely, Engage, Explore, Explain, Elaborate, and Evaluate (Bybee & Fuchs, 2006).

Then Minister for Education Mr. Tharman Shanmugaratnam, in his annual address to principals, teacher educators and education policymakers at the Ministry of Education 2005 work plan seminar, reiterated this: ‘We are progressively shifting the balance in education, from learning content to developing a habit of inquiry. To engage them and prepare them for life than to prepare for tests and examinations’ (Shanmugaratnam, 2005).

**Science resources.**

During this phase, funding was provided to schools to support the teaching and learning of life sciences. Primary schools received funding for an additional science room. Secondary schools were supported with the addition of data loggers in the science laboratories (Tan, Hedberg, Koh, & Seah, 2006). Data loggers are machines that obtain physical data such as temperature and pH of specific environments. They were meant to support the inquiry approach and transform the pedagogy in teaching science during this time. As will be mentioned in Chapter Seven, the provision of additional support does not necessarily transform the pedagogy immediately (Tan, Lim & Poon, 2014). A study conducted by Tan, Hedberg, Koh, and Seah, (2006) reported that more than eight out of ten of the 593 secondary school teachers surveyed used the data loggers for more teacher centred activities and demonstrations. This was in opposition to the objective the equipment was provided for. Changes in pedagogy often require time for teacher learning and are usually not accomplished immediately (Richardson & Placier, 2001).

Two guidebooks providing suggested activities were published to ease the teachers into the teaching of life sciences (Teo, 2003). A book on biosafety guidelines was also published by the Curriculum Planning and Development Division to assist the teachers in the practical activities associated with life sciences. However, as will be mentioned in Chapter Seven, the actual implementation of the curriculum on life sciences was still met with hesitation and
apprehension on the part of the teachers, mainly due to their perceived incompetence of managing the topic. In spite of this, the manner in which the science community attempted to assist in easing the difficulties of the teachers reflected the support provided for science education in Singapore.

In alignment with the Thinking Schools, Learning Nation vision, assessments were adjusted to incorporate more thinking questions (Sellan, Chong & Tay, 2006). Students were required to demonstrate their ability to apply their knowledge to circumstances or contexts that were new to them (Tan, Lim & Poon, 2014). This required higher order thinking skills and not just regurgitation of knowledge.

The approach towards the assessment of science practical skills saw a significant change in 2006 when the School-Based Science Practical Assessment (SPA) was introduced. The previous practical tests were criticised for not encouraging a sufficient number of thinking skills (Toh et al., 1991). The School-Based Science Practical Assessment focused on the assessment on the students demonstrating their skills rather than simply making and recording observations. Students were now required to go beyond making and recording observations to planning investigations, selecting techniques, apparatus, and materials that suit the experimental requirements. This was in more alignment with the incorporation of inquiry skills during the ability driven phase.

However, in its implementation, the School-Based Science Practical Assessment was inundated with challenges (Tan, Lim & Poon, 2014). Teachers found it difficult to play the role of both assessor and teacher to the students. It was also suggested by Towndrow, Tan, Yung, and Cohen (2010), that the teachers did not possess the adequate proficiency in assessment literacy to implement the School-Based Science Practical Assessment to its original intent. Due to the numerous problems, a review was conducted on the future of the School-Based Science Practical Assessment. As of 2017, it was eliminated as part of the national assessment.

Despite the end of the School-Based Science Practical Assessment, it is clear that its introduction was significant in aligning inquiry-based learning and thinking skills in the area of
national science assessments. School-Based Science Practical Assessment was an important advancement of the professionalism of the science teachers in Singapore (Tan, Lim & Poon, 2014). This episode on practical assessment reflected an essential reform that was required for national assessment to be in better alignment with the changing curricular objectives which will be discussed in Chapter Seven and Eight.

The Singapore government started increasing its resources in the area of biomedical sciences, environmental science and interactive and digital media. Programmes to enhance the landscape of life sciences were organised by the Agency for Science, Technology, and Research. Students were encouraged to pursue a career in life sciences through the introduction of science laboratory attachments and interaction sessions with research scientists. Students were encouraged to participate in overseas competitions such as the International Science and Engineering Fair and the Young Physicists’ Tournaments. Singapore students received recognition and awards from these international competitions and that motivated more local competitions as well.

At the end of the ability driven phase, there were improvements in the quality of science education (Tan, Lim & Poon, 2014). Trends in International Mathematics and Science Study found that Singapore was among the top performing countries. The study also reported that students enjoyed the learning of science. Students showed an increase in the ability of the reasoning domains of the test done in 2007 as compared to 2011. This may be attributed to the introduction of the inquiry-based approach. A 2009 Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Co-operation and Development reported that Singapore students performed well amongst top performing education systems around the world. More recently in 2015, Singapore scored the highest in the areas of science and mathematics for the PISA (Tan, 2018).
This chapter has described how from self-governance in 1959 through to post-independence, the key priority of the government was to build up its economy through industrialisation (Goh & Gopinathan, 2008). Science and technical education became an area of focus. The focus on science and technology has remained a key cornerstone of Singapore’s education and economic strategy (Tan, Lim & Poon, 2014).

At the end of the ability driven phase, there were significant changes made towards science education and these were pivotal in spearheading the improvements in science education in Singapore. Students showed a keen interest in learning science and this can be attributed to the teachers who made an effort in upgrading their skills. The numerous policies put in place to address the lack of preparation given to science teachers allowed significant differences in the quality of science teachers.

The next chapter describes the evolution of science education and how educational policies address the acquisition of life skills and 21st-century competencies. Singapore has established an excellent foundation in science teaching and learning in which students acquire the knowledge easily with suitable assessments and practical knowledge. The education system must now evolve not only to teach students how to learn science but also how to use scientific knowledge coupled with creativity and innovativeness (Tan, 2012).
CHAPTER SEVEN
THE CONCERNS OF SECONDARY SCHOOL BIOLOGY TEACHERS

1. Introduction

Chapter Seven addresses the third research aim of this study which is to investigate the concerns and perspectives of secondary school biology teachers in Singapore government schools, with regard to the teaching of biology in Singapore secondary schools. This part of the study aims to provide an understanding of the issues, challenges, and concerns that secondary school biology teachers in Singapore face regarding the teaching of biology. Chapters Five and Six have provided a context for understanding the policies that have impacted the teaching of science and biology in secondary schools in Singapore. As described in Chapter Three, values and perspectives of teachers influence their approaches in curriculum implementation. Therefore this part of the study informs the researcher of the issues, challenges, and concerns that may affect curriculum implementation.

As noted in Chapter Four, the Blackledge and Hunt (1985) framework for perspectives underpins the interpretivist approach to this research question. Within this framework, there are four assumptions which inform us of the importance of everyday activities to society. These everyday activities are influenced by the teacher’s decisions and interactions between people and the environment. These influences negotiate the teacher’s understandings and views which in turn affect their perspectives and hence their curriculum implementation.

Four semi-structured small group interviews were conducted with four randomly selected government schools with a total of twelve teachers. Data for this research was analysed using the qualitative data analysis approach described by Miles and Huberman. The concerns of teachers are presented according to four broad themes that were identified as pattern codes during data analysis, namely the issues with curriculum and syllabus, logistical constraints, assessments, and networking.

The process of data analysis essentially involved five steps. The first step in the analysis was to transcribe the interview recordings. After the recordings were transcribed, they were
organized into a table to allow for ease of note taking, memoing and coding. Through the transcribing process, parts that were not relevant to the concerns of the teachers were removed. The second step was to identify and remove the repeated concerns that were highlighted by the teachers. As the first set of categories were determined, reference back to the interview transcript was necessary. There was a further content reduction when overlapping categories were removed.

The third step was to categorize the data. In doing this, two concerns stemming from the same issue would be categorized together. This step highlighted certain issues that required further research from documentary data. Research from documentary data provided contextualisation of certain concerns highlighted by the teachers. The fourth step involved highlighting the basic themes that emerged from the data. Cross-checking with the interview transcript was required to ensure the categorization was in alignment with what the teachers had said. These basic themes were identified as descriptive codes. Three levels of descriptive codes emerged during the analysis of the interview data. Each level of descriptive codes is reported in this chapter. For example, the descriptive codes that emerged within the theme of curriculum and syllabus were the concerns the teachers had with regards to the inquiry approach and the introduction of molecular biology into the syllabus. Both concerns are addressed together with the second level and first level descriptive codes that emerged during the data analysis process. The fifth step was to categorize these descriptive codes into broader themes. Four broad themes or four pattern codes emerged: curriculum and syllabus, logistical constraints, assessments, and networking. Propositions emerged through the data analysis process and these propositions are further described in Chapter Eight.

This chapter is organized into the four broad themes that emerged. The numbers and letters that appear in parenthesis in this chapter refer to the coding system for identifying the transcripts of interviews. A sample of the descriptive codes and pattern codes derived from the interview data is shown in Figure 7.1. This provides a brief overview of the findings from the interviews conducted as well as the organisation of this chapter.
Fig 7.1 Display of coded data
2. Teachers’ concerns associated with the biology curriculum and syllabus.

The teachers’ raised two main concerns with the biology curriculum and syllabus. The first concern was based on the introduction of the topic of molecular biology into the syllabus. The second concern focused on the introduction of the inquiry approach into the curriculum.

Before describing these concerns, it is important to provide a brief definition of ‘curriculum’ and ‘syllabus’ and to describe the curriculum review process in Singapore. In a theoretical sense, curriculum refers to what is offered by the school or college. However, in the practical sense, it has a wider scope which covers the knowledge, attitude, behaviour, manner, performance, and skills that are imparted in a student. The syllabus is defined as the documents that consist of topics covered in a particular subject which serves to support the curriculum. The syllabus focuses more on the topic and the parameters the teacher should follow when teaching.

The science curriculum in Singapore undergoes a six-year review cycle. The Curriculum Planning and Development Division of the Ministry of Education in Singapore conducts zonal teacher networking sessions in which the division officers elicit feedback from the teachers regarding the syllabus. With this feedback, a syllabus review is conducted with a syllabus review committee. The committee, headed by the Minister of State for Education, comprises representatives from Ministry of Education, Singapore Examinations and Assessment Branch officers, curriculum planning officers, lecturers from the National University of Singapore as well as the National Institute of Education and government school teachers. Curriculum planning officers present their findings to the syllabus review committee. Syllabus changes will be informed to lecturers from the National Institute of Education and current heads of science departments in school. This will allow the National Institute of Education to adjust their training and courses for beginning teachers and in-service teachers according to the changes (P1:4:6:1). The heads of departments then highlight the changes to the in-service science teachers for appropriate execution during teaching.
2a. Introduction of molecular biology

The biology syllabus was reviewed and changes were implemented in the year 2000 to ensure that concepts and skills fundamental to students’ access to the new fields of life sciences were incorporated (Tan, Lim & Poon, 2014). In 2008, the introduction of molecular biology topics into the secondary school biology syllabus was to ensure that the biology syllabus moved together with the growing international landscape of life sciences.

According to Kampourakis (2018), arguably the most significant change in biology over the past century has been in molecular biology. Molecular biology can be described as a perspective that biologists use to explain the phenomena they are studying. Morange (2000) has suggested that molecular biology should not be considered as a sub-discipline of biology, but as a specific level of explanation which is demonstrated through sub-disciplines of biology such as molecular genetics. As mentioned in Chapter Six, life sciences involve the scientific study of life and organisms, such as microorganisms, plants, and animals including an extended aspect on molecular genetics, specifically on the study of Deoxyribonucleic Acid (DNA).

As mentioned in Chapter Four, a professor from the National Institute of Education was interviewed for the purpose of this research and she reinforced the objective behind the inclusion of molecular biology topics into the curriculum during the interview.

We need our students to learn what is current and what is cutting edge. It is a necessary move, lest the students know how science has changed and evolved (P1:5:3:1).

She also emphasised the need for Singapore to remain current in its approach towards education and the sciences. The country’s competitive edge is dependent on the ability of our education to evolve together with its economy. This is highlighted in both Chapter Five and Six as the education-economy relationship. Therefore it is important to ensure that concepts and skills fundamental to students’ access to the new fields of life sciences are incorporated into the syllabus (Tan, 2015).
In addition, Kampourakis (2018) adds that the role of molecular biology education in the formulation of an understanding of molecular phenomena is fundamental to understanding key processes at higher levels and is essential for all life science studies. As Duncan and Reiser (2007, p. 939) stated, “understanding genetic phenomena entails understanding how mechanisms and interactions at the molecular (genes, proteins) and micro-levels (cells) bring about effects at the macro-level (organism, population).”

Schools were provided with more support and funding to support this review of syllabus. In 2003, a Deoxyribonucleic Acid (DNA) centre was set up at the National Institute of Education to address the growing emphasis on life sciences and the need to train and educate teachers in these concepts (Teo, 2003). In 2003, the DNA Learning Lab was opened at the Singapore Science Centre. The centre collaborated with the DNA Learning Centre at Cold Spring Harbour in New York to distill cutting-edge research work in the life sciences (e.g., DNA extraction, bacteria transformation) into simple experiments accessible to young students (Tan, Lim & Poon, 2014).

**Inclusion of the molecular biology topics.**

The syllabus was adjusted to allow the inclusion of the molecular biology topics which inadvertently saw the *reduction of other biology topics*. These topics such as muscles, teeth, and bones were considered to be classical biology topics by the senior biology teachers. This reduction raised a concern for the teachers. The move was not without its detractors who were concerned that there was too much emphasis on molecular biology at the expense of curriculum time for learning about classical macro-biological systems such as ecosystems and animal physiology (Tan, Lim & Poon, 2014). Such debates also reflected the ongoing tensions in deciding on the scope of the national curriculum. The Ministry of Education has often maintained the need for the curriculum to remain concise such that any additional contents introduced to update the curriculum have to be accompanied by the corresponding removal of topics, which often becomes a difficult decision to take as it has implications for the different stakeholders such as the teachers. Some of the teachers interviewed felt that the objective of
biology education is to prepare students for life and living and an understanding of the
environment and not so much an understanding of molecular biology.

Biology is the study of life and the relationship of living things as well as an appreciation
of man and his environment. (S2:21:7:1)

Whilst the teachers recognised that molecular biology brings into the classroom modern
science concepts which are relevant and important in ensuring Singapore is in alignment with
new scientific discoveries, they expressed concern with the reduction of the classical biology
content.

The world is changing; the science field is changing. There are so many discoveries.
However, the essence of biology education is in the study of animal and plant physiology.
(S1:4:3:1)

The sentiment shared was consistent with most of the teachers interviewed. The
reduction in classical biology content was inevitable in the face of a changing landscape of
science education; however, most of the teachers were concerned that this reduction of content
would have a detrimental impact on students’ mastery of the content of biology in its entirety.
In addition, some teachers commented that molecular biology is not consequential to the holistic
learning of biology at the secondary school level. Molecular biology topics are observed to be
covered in more detail at the post-secondary level. Therefore some teachers questioned the
necessity of the implementation of molecular biology topics at the secondary school level.

Some teachers commented on the abstract nature of the molecular biology topics. The
teachers questioned the students’ level of scientific literacy at a secondary school level and its
alignment to understanding molecular biology. Scientific literacy in this regard refers to the
ability of the students to understand complex scientific theories. One of the main attributes of
scientific literacy according to Miller (1983) and Thomas & Durant (1987) is the ability to
understand scientific terms. As mentioned in Chapter Three, it is a well-recognized struggle for
students regarding the topic on life sciences and genetics.
The students have trouble understanding some of the terms. They are similar in sound and in spelling and they are often confused. One example is phenotype and genotype. (S1:5:10:2)

Students are likely to find more difficulties with terms in biology than in chemistry or physics (Tan & Subramaniam, 2009). This concern resonates with the concern shared earlier questioning the necessity of teaching molecular biology at the secondary level instead of post-secondary. The maturity of mind could perhaps aid in the scientific literacy of a student and allow for more effective acquisition of an abstract topic such as molecular biology. As mentioned in Chapter Three, the invisibility and inaccessibility of genetics concepts make the subject complex and abstract (Marbach-Ad & Stavy, 2000) and therefore difficult to understand.

The students have trouble understanding the concept of genetics. They are not able to see physical DNA and therefore have trouble visualizing it. (S3:23:4:1)

According to Kampourakis (2018), this invisible phenomenon is difficult for students to understand, therefore making reasoning about it challenging. In addition, Duncan & Reiser (2007) highlighted the fact that there are several different levels of organization within the molecular biology level that further confuse students.

Teaching of the molecular biology topics.

The teachers interviewed read different science majors in a university such as microbiology and biotechnology. However, after teacher training at the National Institute of Education (NIE), they all assumed the position of biology teachers. As mentioned in Chapter Six, there are differences in the teaching of biology, chemistry, and physics. However, the key ideas of assessment, nature of science, science laboratory work, conceptual understanding and key strategies (such as questioning, scientific argumentation, flip classrooms etc.) in all of the different sub-disciplines are addressed at the NIE (Tan, 2018).

According to Tan (2018), an assumption is made that teachers possess current and adequate subject mastery since the pre-requisite for admission into the NIE program is a first
degree in the relevant field. As such, specific content of physics, chemistry and biology is not included in the program. Tan (2018) explains that although this assumption may be largely valid, there are instances where this assumption breaks down.

Therefore, some of the teachers felt they were insufficiently trained to teach the molecular biology topics that were introduced. According to Van der Zande et al. (2012), there are four specific areas of expertise that are required for the effective teaching of molecular genetics. Firstly, subject matter expertise; secondly pedagogical content knowledge; thirdly interpersonal expertise; and lastly moral expertise. Subject matter expertise refers to content knowledge and pedagogical content knowledge is essential to represent the subject matter in a way that the student conceptions and learning difficulties concerning that specific subject matter are accounted for. Interpersonal expertise refers to the ability to build relationships with students (Wubbels, Brekelmans, Den Brok, & Van Tartwijk, 2006) and moral expertise refers to the ability to clarify the normative component of socio-scientific issues (Van der Zande et al., 2012).

Most of the teachers interviewed expressed difficulty in the first and second area of expertise as stated by Van der Zande et al. (2012). The concern cited was that they did not have expertise concerning the subject matter. The introduction of the molecular biology topics forced the teachers to re-learn the molecular biology concepts. An improvement or re-learning is required not only for the content knowledge of the teachers but also pedagogical knowledge (Tan, 2018) to suit the incorporation of molecular biology into the syllabus. Some of the teachers interviewed expressed increased levels of anxiety and stress when re-learning of content had to take place.

It becomes very stressful for teachers because re-learning has to take place. We have all been trained in a particular field, but when new science comes in, we are expected to re-learn a large amount of knowledge (P1:4:3:1).

In-service teachers struggled to find the time to attend the courses and workshops planned for them. In addition to marking and planning for lessons, the teachers are expected to
attend courses and workshops to facilitate in their re-learning process. Workshops and courses are provided by the Academy of Singapore Teachers as well as the National Institute of Education for in-service teachers. The academy aids in driving pedagogical leadership to raise the level of professional practice in the classroom and expertise across the system.

We relied on textbooks and the internet mostly, to update ourselves with regards to the content. Also, of course, we helped one another (S1:10:4:2).

It is important to determine subject matter expertise when teaching molecular genetics. This would include current school subjects as well as recent content from research discoveries (Van der Zande et al., 2012). Therefore it is essential for teachers to keep abreast of the current content knowledge in the area of molecular genetics.

Teachers also raised the concern of insufficient resources required to teach effectively molecular biology topics. For example, the studying of DNA is often aided by experiments, which are hands-on activities conducted in the science laboratories, involving the Polymerase Chain Reaction machine. Due to high cost, very few schools own such a machine.

To teach DNA effectively, there would be a need for the PCR machine. However, only one school in our cluster owns one (S2:14:3:1).

In this instance, a cluster refers to a group of schools which are located within a specific area in Singapore. Cluster schools participate in networking, sharing, and collaboration with each other to raise the capacity of the leadership teams and the level of performance in each school. However, due to occasional logistical constraints, such as limited time, teachers may not be able to utilise teaching resources such as the Polymerase Chain Reaction machine from the cluster schools.

As mentioned earlier, pedagogical content knowledge is an important tool in the teaching of molecular genetics. Some of the teachers expressed a concern that their repertoire of pedagogical skills was insufficient in allowing an accurate representation of the subject matter. This also stemmed from their lack of confidence in the content. Many of them expressed the
attempt at adopting alternative methods of investigating the concept of DNA. Some used videos and animation while others chose to conduct simple science experiments in the science laboratory. However, the teachers did comment on the absence of the spirit of discovery and inquiry in explaining the molecular biology concepts due to the limited resources and pedagogical content knowledge.

The students are so bored watching video after video. They prefer to perform hands-on activities. However, with the DNA chapter, it is very difficult (S2:30:3:2).

Teachers also indicated that the materials provided, such as textbooks and workbooks, did not provide a suitable mode of assessment for the molecular biology topics. The questions in the workbooks were based on low-level questioning skills and were insufficient in assessing the students on inquiry skills with regards to the molecular biology topics.

The questions were insufficient. We used our own worksheets for the topic on Molecular Genetics and Heredity (S3:8:3:1).

As mentioned earlier, a DNA centre was also set up at the National Institute of Education in 2003 to provide teachers and students with hands-on experience of investigations in the area of life sciences (Teo, 2003). A similar DNA Learning Lab was set up at the Singapore Science Centre in 2003 as well to make the knowledge of life sciences accessible to younger students. Unfortunately, the teachers required more assistance in their day to day classroom teaching of the topic. The Curriculum Planning division also published a book with biosafety guidelines to provide schools with information on the handling of biological samples and contamination. However, the teachers felt that the book served more as a guide for safety measures rather than support in teaching and learning.
2b. Inquiry approach

A significant shift was made in the curriculum to give greater emphasis to teaching and learning science by inquiry to nurture students’ curiosity, inquiring minds, higher-order reasoning skills and problem-solving skills (Lee et al., 2008). There was greater emphasis on using hands-on and more open-ended investigations to encourage students to move away from mechanically following instructions to more self-directed learning and creative thinking (Chin & Kayalvizhi, 2002). The objectives of the inquiry approach will be discussed in the next section, followed by the concerns the teachers expressed with regards to the implementation of the inquiry approach.

The 2008 revamp in curriculum gave explicit emphasis to inquiry in the teaching of science. Science as inquiry suggests that science teaching is no longer only about students’ acquisition of content knowledge but also about skills, strategies, and habit of mind associated with decision making and problem-solving (Tan, Talaue & Kim, 2014). The science syllabus was adjusted to free up curriculum time for the introduction of thinking skills (Tan, Lim, and Poon, 2014).

Most of the teachers interviewed are supportive of the inquiry approach. They articulated that science teaching should no longer be only about students’ acquisition of content knowledge.

It is important for students to learn how to creatively seek knowledge rather than merely memorizing content from textbooks (S3:9:3:1).

However, they highlighted certain concerns that affect their execution and their inclusion of the inquiry approach in their classroom teaching.

The enactment of science as inquiry have brought to the surface various difficulties and tensions (Tan, Talaue & Kim, 2014). Despite structured approaches to support the implementation of the inquiry approach, research in international communities of science education shows that the implementation has been a daily struggle for science teachers

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(Crawford, 2007). The implementation of science as inquiry is challenging due to reasons such as students’ attitudes towards the approach, teachers’ competencies and belief system and lack of administrative support in the area of assessment implementation in alignment with the inquiry approach. These challenges are discussed in turn.

Some of the teachers interviewed held the view that students were not ready to participate in inquiry teaching because the approach was new to them. Students’ attitudes towards the inquiry approach were observed to be indifferent due to the fact that they are accustomed to teaching that provided model answers in preparations for examinations (Tan, Talaue & Kim, 2014).

An important difference between the traditional classroom and an inquiry-based classroom is the role played by the students (Tan & Tan, 2014). In traditional classrooms, students play a passive role as recipients of knowledge. An inquiry-based classroom aims to develop students as active learners who take ownership of their learning. Such autonomy in their learning may allow them to set the direction of how the lesson progresses. In order for the teacher to orchestrate inquiry-based learning, they must know where their students are located in the learning journey (Tan, 2015). This requires the teacher to elicit information actively and continuously about students’ learning (Black & Wiliam, 1998). Some of the teachers interviewed expressed the concern that the upper secondary students (15-16 years old) were observed to be non-receptive to the inquiry approach as compared to the lower secondary students (13-14 years old).

The lower secondary students are still at an inquisitive age where they are willing to take part in the inquiry-based activities without much hesitation (S4:10:2:2).

The teachers teaching lower secondary students are not limited by time to complete the syllabus; therefore, there is the freedom of exploring inquiry approaches in their teaching. The teachers also do not feel the pressure of national examinations for the lower secondary students and therefore are willing to explore more alternative approaches towards science.
The stakes are lower at the lower secondary level. That gives us the space and time to explore the inquiry-based activities. (S3:11:2:1)

The upper secondary students, on the other hand, are more concerned about their national examinations. They would rather be taught the content in its entirety without the frills of an alternative pedagogical approach such as the inquiry approach. One teacher highlighted that this attitude might stem from the pressure they receive at home. Their parents are particularly concerned about the national examinations and the academic performance of their children.

The students are worried about failing, and they want to know how to do well academically. Some of their parents have very high expectations for them (S2:40:2:1).

Another teacher cited that the upper secondary students have developed an attitude of complacency in their learning. They tend to expect the answers rather than think through the questions posed by the teachers. There is a lack of desire to self-regulate their own learning, and instead, they are more inclined to expect answers from their teachers. Hence, they consider the inquiry approach to be tedious and time-consuming.

The students expect the ‘textbook’ answers even before trying the questions on their own. (S4:33:4:1).

After conducting a lesson incorporating the inquiry approach, one of the teachers interviewed was asked about the objective of the inquiry approach by some of her students questioned. The students queried further on why the lesson could not be taught in the regular didactic manner. With reluctance to adhere to the inquiry approach, students are non-participative, and this posed a further challenge for the teachers.

One of my students said to me, ‘Why can’t you just tell us what is important for this chapter, what will come out for the exams? Why do we have to do this activity?’

(S1:28:2:3)
One teacher shared that implementing the inquiry approach requires a culture that needs to be cultivated. The students have conformed and found comfort in the didactic manner of teaching. Displacing the stability they acquire from didactic teaching and placing them in a setting of unpredictability with the inquiry approach is an arduous task.

In addition to the above-stated concerns, there were a number of teachers who highlighted that the students' weak grasp of the content added to the inability to implement the inquiry approach during lessons. The students are not sufficiently equipped, content-wise, to answer the inquiry questions posed at them.

I have had students who cannot even understand the simple concepts in the class. If I were to incorporate inquiry into the lesson, these lower ability students would lose out (S2:9;3:2).

As mentioned by the teacher quoted above, some students may not benefit from a class-wide implementation of an inquiry approach. Higher-ability students, according to the teachers, would best benefit from inquiry teaching, whereas lower- and middle ability students could be disadvantaged. Some teachers felt that the inquiry approach was forced fit into the curriculum without addressing the different learning styles of the students.

However, this concern may be a biased perspective of what the teachers deem the students can handle based on their behaviour in class or their attitude towards learning. There is a general biased perception that science as inquiry can be implemented only for students with above-average abilities (Dietz & Davis, 2009; Moseley, Ramsey, & Ruff, 2004). This perception may not be true in all cases. The inquiry approach focuses on allowing the students to create their knowledge and develop perceptions of content. It holds little or no regard to the perceived intellectual abilities of the students. In the next section, the teachers’ concerns regarding their own competencies to implement the inquiry approach are discussed.

While students in Singapore have been doing fairly well in international benchmarking studies, such as the Trends in International Mathematics and Science study (Bybee & Fuchs, 2006), research into classroom practices have brought to the surface areas for improvement.
According to a study by Luke, Freebody, Lau, and Gopinathan (2005, p.11), Singapore’s science classrooms displayed a largely ‘didactic, traditional and rote reproductive character of pedagogy’, which falls short of the Ministry’s call for a more student-centric active learning environment (Tan, Lim & Poon, 2014).

The intentions of curriculum developers or teachers, as is increasingly conceded, often do not map well onto actual classroom practices or enacted curriculum (Tan, 2015). Attention has to be paid to another aspect of curriculum development that has been less emphasised which is the curriculum implementation (Lee & Chue, 2013).

The teachers interviewed shared that they were limited by their own competencies with regards to implementing the inquiry approach. Teachers are not able to adapt to implementing alternative curriculum approaches if they do not have sufficient knowledge on the subject matter of science and its practice as a form of inquiry (Harlen, Brand, & Brown, 2003). The teachers’ interpretation and implementation of curriculum changes may not always be consistent with the intent and the expectations of the implementation body (Lefstein, 2008). Therefore it is paramount that the teachers understand the approach and how to implement it (P1:3:5:1) as discussed in Chapter Three. The issue with the teachers implementing the inquiry approach on their own is that the intended outcome of the approach may not be realized in its entirety. One of the main reasons for the number of workshops and course organised by NIE and AST was to ensure the teachers’ implementation of the inquiry approach is aligned with the intended outcome (Tan, Lim & Poon, 2014).

Some of the teachers interviewed voiced the concern that they are not confident to deliver an inquiry-based lesson because of this lack of understanding of the inquiry approach. Therefore many of them struggled in producing a suitable inquiry-based lesson.

I don't have much experience in implementing an inquiry lesson. I am so used to teaching a teacher-centred lesson (S2:10:5:1).

The National Sciences and Science Education Academic Group at the National Institute of Education developed five customised courses on the inquiry approach since 2007. The
objective was to ensure the professional development of the teachers in understanding the inquiry approach. However, the in-service teachers found it very challenging to find the time to attend these courses. Instead, the teachers continued to struggle to implement the inquiry approach on their own.

We talked amongst ourselves regarding the best way to implement inquiry in biology.

There was hardly ever a chance to speak to teachers from other schools (S2:10:2:1).

Teachers feel that inquiry may not be the best approach to teaching biology. Most of the teachers interviewed feel overburdened and lacked the time to meet the demands of the inquiry approach.

Another issue that was highlighted by the teachers interviewed was that the inquiry approach does not have a proven record of positively contributing to the students’ academic results. The teachers were concerned that if they abandon their trusted approach of drill and practice, the students’ academic results may be affected.

What if the students don’t understand the content when it is taught in another manner? We would have to revert to the regular style of teaching. Quite a lot of time wasted. (S2:16:7:1)

The high-stakes national examinations exert great demands on the teachers’ time. While some of them believe that an inquiring mind is valuable, it does not guarantee good performance in examinations. In order to meet performance expectations, teachers feel the need to do minimal inquiry teaching and instead focus on more direct forms of teaching. The lack of teacher belief affected the successful implementation of the inquiry approach. Beliefs are based both on the teachers’ interpretation of the interplay between reform innovations and actual classroom events and as filters for decision-making on instructional goals and classroom management (Luft & Roehrig, 2007). The teachers have a strong sense of accountability towards the students and their academic results. This was one of the reasons why some of the teachers interviewed refrained from adopting the inquiry approach at upper secondary level.
classes in its entirety. The next concern related to the inquiry approach is on the issue of assessment.

Teachers feel that ensuring congruence between the inquiry approach and assessment is one of the important aspects of ensuring effective implementation of the inquiry approach. However, many of the teachers interviewed expressed that the current assessment framework and the inquiry approach are incompatible. The current assessment practice does not encourage inquiry. Instead, it focuses on recall and application of content, more summative style assessments.

When inquiry was first introduced, the majority of the questions in the paper require the students to memorize or recall content. Lately, there seems to be more thinking questions (S2:38:2:3).

However, it was noted through the interviews with the teachers, that there had been an increase in data based questions in the national examinations in recent years. This inclusion of data based questions allows for a more formative approach to assessment.

Another struggle that was highlighted was that the teachers have a lack of understanding of formative assessment. Therefore even though they are aware that formative assessment would ideally support the inquiry approach, they are challenged in ensuring that the assessments they are administering are truly formative.

I have created worksheets and quizzes that I think are in alignment with the inquiry approach, but I am still not sure if it is formative in nature. This makes me question whether I should implement it. The other thing is that we have no sample worksheets or quizzes in formative style to refer to (S4:11:9:1).

The teachers raised the concern that there is a lack of resources to support the inquiry approach. Providing a sample of formative assessments would greatly alleviate the concern and the lack of knowledge of formative assessment. Concerns on assessment in other contexts emerge
as a pattern code and are described in the section on teachers’ concerns associated with assessments.

3. Teachers’ concerns associated with logistical constraints.

Logistical constraints in this context refer to any physical parameters that may have a consequence on the implementation or the organization of secondary school biology lessons in Singapore. The teachers are cognisant of the logistical constraints when they are selecting tasks for students. The main concern highlighted by the teachers relates to the lack of time the teachers face in completing the prescribed syllabus.

3a. Time

Throughout the interviews, the lack of time required for completion of the syllabus was a repeated concern that was raised by the teachers. There are three concerns that were highlighted by the teachers with respect to the factor of time. They are the implementation of alternative pedagogies, the revision process in schools and the mandatory after-school lessons that are scheduled.

Due to the overwhelming demands of the syllabus, most of the teachers interviewed avoided the implementation of alternative pedagogical approaches. According to a study done by Tan and Tan (2014) on teachers’ ideas and concerns with assessment practices in inquiry science, they discovered that while students’ learning is an important consideration for teachers, other practical considerations, such as time constraint, may result in teachers forsaking any perceivably complex tasks for the more routine ones. The teachers interviewed for this study iterated a similar concern. The teachers tend to choose simple approaches to teaching that require minimal preparation and execution time. This was done to ensure completion of syllabus.

As a beginning teacher, I used to adopt all kinds of approaches to teaching, but now I realized there is very little time to finish the syllabus, especially for the Secondary Four students (S2:3:1:2).
There was a consistent perspective shared amongst the teachers interviewed that they felt the pressure to be accountable to the students, the school’s management and their students’ parents for the students’ academic success. Generally, the teachers felt that assessment demands compelled them to teach in a didactic manner and these constraints caused by the demands of assessments were intensified by the lack of time to complete the syllabus. As mentioned earlier, teachers understand the effectiveness of the inquiry approach; however, because of the limited time, they choose not to infuse inquiry into their classroom. Therefore teaching approaches were largely influenced by assessment demands.

The limitation of time was a factor considered by the Ministry of Education when the inquiry approach was introduced into the science curriculum. Provisions were made to ensure more time was freed up for the teachers to embark on this approach. However, according to the teachers interviewed, the provisions for time were insufficient in ensuring effective implementation of the inquiry approach.

We are aware of the reduction in the syllabus when the inquiry approach was introduced. However certain topics such as the molecular genetics topics require a significant amount to teach. The freed up time did not make a difference (S4:10:19:3).

According to a study done by Lee (2017) on the perspectives of teachers on the history curriculum in Singapore, the inquiry approach could not be implemented effectively without compromising the assessment readiness of the students. Most of the teachers interviewed echoed similar sentiments regarding the lack of time to implement inquiry lessons. The preparation and execution of the inquiry lessons were too time-consuming. Therefore, teachers made the choice to focus on assessment readiness rather than infusing inquiry into the lessons.

Schools often attempt to complete the syllabus by the middle of the Secondary Four year. This is to ensure adequate time for content revision. However, the syllabus was created on a two-year timeline, hence finishing it in one and a half years will pose a problem for the teachers and the students. Most teachers interviewed raised the concern that students tend to
forget the Secondary Three topics taught the year before and therefore revision is essential before the national examinations.

The students tend to forget what has been taught the year before. And O levels is an assessment of both Secondary Three and Secondary Four work. Revision is a must (S1:6:3:1).

The teachers face an enormous amount of pressure in carrying out their responsibilities in preparing students for the examinations. Some of the teachers interviewed did express the desire to teach without focusing so much on examinations or assessment standards. However, the stakes are too high in an assessment focused system like Singapore’s.

In an effort to ensure the students complete syllabus and are suitably prepared for the assessments, teachers highlighted that they often conduct after-school lessons or supplementary lessons. Teachers are allocated between 120 – 140 minutes per week for biology lessons and the teachers felt that this time is insufficient in completing the syllabus.

Despite the fact that we are allocated four periods a week, there are weeks when we don’t receive the full four periods. Sometimes due to school events or public holidays (S4:5:2:2).

Therefore in addition to the regular school hours, teachers and students often remain after school to ensure syllabus requirements are fulfilled. This brought about lethargy and stress in the students as well as the teachers. This may not be an optimum learning environment for the students. In addition, this may also not be an optimum working environment for the teachers.

During remedial, some of the students do not even turn up or even worse, turn up but fall asleep (S1:25:2:1).

Therefore even though, remedial, or after school classes, was an option adopted by most teachers to complete the syllabus, some teachers voiced the concern that the remedial lessons were not conducive, in terms of timing, to allow an optimal learning experience.
The concern raised by the teachers was that if 120-140 minutes were allocated per week for biology, and 60 minutes was taken for the teaching of essential laboratory practical skill sets, an additional 60-80 minutes will be insufficient in completing syllabus. Therefore, with an already limited amount of time for completion of the teaching of theory content, the teachers were also struggling with the completion of the teaching of laboratory practical skill sets.

4. Teachers’ concerns associated with assessment.

Assessment is an integral part of the school experience. Assessment refers to a collection of the students’ work for the teacher to make a sound judgment on the students’ progress. Following Scriven (1967), assessment can be broadly categorized into two main types, namely formative assessment, and summative assessment. Formative and summative represent two types of assessment interpretations of information at two differing times. Both types of assessment will be discussed in turn.

4a. Summative assessment

Summative assessments are used as a measure of how much the student has learned throughout the programme or the lesson. Summative assessments are normally conducted at certain points throughout the year to provide the teacher or the educator with a measure of how much the student understands (Nitko, 2004). There have been some claims that summative assessments limit the scope of teaching and narrow the curriculum (Popham, 2003). This is because summative assessment focuses very strictly on the content being taught and not on ideas or thought that might have arisen from the teaching and learning process.

In Singapore, assessment practices have been summative and aimed at evaluating what students have learned and gained from school. However, concerns were raised with the emphasis on summative assessment. Some teachers raised the concern that the students lacked thinking skills and were too focused on achieving results. Some teachers interviewed felt that the summative mode of assessment has limited the thinking of the students to such an extent that they experience difficulty in thinking and handling adverse situations.
The students have become reliant on the answers provided. They are too lazy to think (S4:26:5:1).

Some teachers felt that it would be impossible to eradicate summative assessment completely from the assessment profile in Singapore. Summative assessment, despite some of its setbacks, is a guaranteed method of assessing students for placements into streams that would suit their learning pace. It is one of the definite ways in which a teacher can determine a students’ understanding of the content taught. In addition, Singapore is a meritocratic society in which large emphasis is placed on grades. Entry into post-secondary educational institutions as well as the acquisition of jobs is based on achievement of grades and qualifications.

We can try to conduct other forms of assessments in the classroom, but the most reliable way to know if the students have learned is through summative assessments (S1:17:3:2).

The then Minister for Education of Singapore, Tharman Shanmugamratnam explains why Singapore remains to emphasise the importance of summative assessment –

They (examinations) provide transparency in the system and give parents and students confidence that access to a school or tertiary institution is based on merit – confidence which is often lacking in other systems (Hung et al., 2009, p.213).

4b. Formative assessment

As education in Singapore embraces the inquiry approach, there has been a necessary shift of assessments to a formative style of questioning. This allows the students to take more ownership of their learning. The students are also encouraged to think outside of the scope of the syllabus. Formative assessment type questions have increased in appearance in the national examinations. For example, the demand on the students to articulate the connection between the analysis of a graph and their theoretical biology knowledge has increased. Application of knowledge is required, and higher order thinking is necessary.
Formative assessment is an alternative mode of assessment and is intended to aid learning. It is closely associated with curriculum and pedagogy and is said to be central to good teaching practices. Formative assessments are more open-ended and are considered to provide students with a platform to understand their weaknesses and strengths. This allows the students to develop ownership over their own learning (Harlen & James, 1997). Black and Wiliam (1998) indicated through 250 studies that suitable formative assessment could serve to increase the learning of students. The implementation of formative assessment, however, is dependent on the teachers’ content knowledge and understanding of the students.

The idea of formative assessment is relatively new for most teachers in science classrooms (Tan, Lim & Poon, 2014). As mentioned in the previous section, under the inquiry approach, teachers struggle with the implementation of the approach due to many reasons. They are concerned about their own competency and knowledge about formative assessment and they are unsure of the reliability of formative assessment in accurately assessing the students’ abilities. They are also not confident of the resources available in implementing the formative assessment approach in the science classrooms. However, there were some teachers interviewed, who welcomed the change towards formative assessment. These concerns will now be addressed in turn.

The teachers were not completely confident in implementing formative assessment accurately. The teachers expressed a lack of knowledge on how formative assessment is conducted. This lack of knowledge impeded their accurate implementation of formative assessment. As mentioned earlier, any implementation of alternative pedagogy or assessment approach is strongly dependent on the teacher’s accurate knowledge of the manner in which the approach is intended. The teachers lack the knowledge and competency and therefore lacked confidence in implementing the approach successfully. This was evident from the perspectives provided by the teachers interviewed.

Formative assessments may help in ensuring learning takes place when alternative pedagogy is adopted. However, the teachers interviewed felt that it should not be an assessment
that is taken into account for placement of students. These teachers felt that it is not necessary to
shift towards formative assessment. They have a strong belief in the current assessment practice
(S2:21:5:1). The teachers interviewed questioned the reliability of the formative assessment.

How do we know if the students have learnt the content we have taught? (S1:12:3:2)

This lack of confidence in the formative approach ultimately stemmed from the lack of
knowledge the teachers have on formative assessment. Some of the teacher interviewed did
express an interest in learning more about formative assessment in order to allow them to
accurately implement the approach.

Some teachers felt that the resources provided do not address the formative assessment
style. Despite an emphasis on the formative assessment approach, teachers expressed a lack of
support from the publishers of the workbooks available for the students.

The workbooks we have now have minimal formative style questions. They are more
recall questions (S1:31:9:1).

To address this shortage of resources, teachers spend a significant amount of time
creating worksheets and assessments from scratch. These worksheets and assessments are based
on the data based style of questioning.

As mentioned earlier, some teachers welcomed the change towards formative
assessment. They were eager to learn more about it and implement it in their classroom. These
teachers expressed the need for more thinking skills to be incorporated into the curriculum.

Formative assessment may actually allow the students to acquire important thinking skills
that are lacking in their regular assessment processes. (S4:11:2:6)
5. Teachers’ concerns associated with networking.

Networking is a form of professional development for the teachers. Engaging in networking amongst their peers has been proven to provide a positive impact on teachers especially in the area of innovation in the classroom. The sharing conducted during networking allows teachers to adopt each other’s teaching tools and implement it according to the profile of their own students.

The concern regarding networking emerged as a pattern code during the analysis of the interview data. It is noted, however, that it was not an obvious pattern code that emerged. The concern was one that the researcher found necessary to highlight to promote improvement in policies and processes.

5a. Current networking initiatives

There are numerous platforms provided in Singapore for the networking of teachers. The Academy of Singapore Teachers was set up in 2010 for the sole purpose of providing a learning platform for teachers in the form of workshops and classes. For biology teachers, there is a specific academy known as the Biology Chapter. The Biology Chapter was set up to create a support network for teachers teaching biology in Singapore secondary schools. The objectives of the workshops and the seminars are to provide opportunities for networking among biology teachers in a meaningful and sustained manner as well as to encourage intellectual discourse and the exchange of ideas with the sharing of classroom innovations using technology to engage deep learning.

In addition, a School Staff Developer is allocated to each school to aid in the professional development of the staff. The school staff developer will ensure that the professional development of the teachers is well taken care of through a training roadmap which is decided upon at the beginning of the year.

Recently the Professional Learning Communities initiative was announced in 2009. The professional learning communities are expected to inculcate the culture of teacher-led
professional development. The networking during professional learning time is amongst the teachers within the school.

**5b. Concerns regarding networking**

All of the teachers interviewed attested to the well-developed structure of professional development in Singapore. However, most of them felt that networking would be more suitable if done with teachers from comparable schools.

The teachers felt that networking should be categorised according to the profile of students- in other words, a networking session of Biology teachers of comparable schools. The concern raised was that pedagogical approaches might differ depending on the profile of the students.

The strategies encouraged or taught during the workshops are usually for higher ability students. Some of the teachers interviewed felt that it would be more suitable to conduct courses or workshops for the teacher within the cluster. This will allow the teachers who are teaching the students of similar profiles to not only learn useful and meaningful strategies but also network amongst themselves. Teaching biology is not just about the content and the right pedagogy but also about the engagement and class management. Students of different profiles and backgrounds respond differently to different types of engagement tools and pedagogy. It is inequitable to assume one strategy would suit every student.

This chapter has addressed the third research aim of this study which was to investigate the concerns of secondary school biology teachers in Singapore government schools, with regard to the issues they face in their everyday working lives. Four broad themes emerged from the interview data: curriculum and syllabus, logistical constraints, assessments, and networking.
CHAPTER EIGHT
SUMMARY AND DISCUSSION

1. Introduction

Education in Singapore has been shaped by historical and societal forces through three different stages of governance since the 1920s. With little or no natural resources, Singapore has a heavy reliance on human capital (Tan, Lim & Poon, 2014). The education sector, therefore, became a focal point in ensuring the economic success of the nation. Recent advancements over the last two decades have led to an exponential increase in the content of biological knowledge and the issues of today have become increasingly bio-social in nature. This has led to biology receiving more emphasis in its position to drive the economic success of Singapore. This study, therefore, illustrates the importance of this education-economy relationship through the study of the historical background and the recent developments of the education system and the manner in which the teaching of biology and science evolved in alignment with the changing economy.

This concluding chapter is organized into five sections. The first section overviews the study by restating the research aims of the study as well as outlining the research methods employed. The second section summarizes the findings developed from the three research questions in this study. The third section discusses the propositions derived from each research question. The fourth section focuses on the transferability of the findings of this research, in the area of policy and practice and further research. The fifth section concludes this thesis.

2. Overview of the study

2a. Research aims

This study had three aims.

The first aim was to develop an understanding of the historical background to the development of the education system in Singapore from the colonial times, in 1920 until 1958 with special reference to the development to the teaching of science in secondary schools. This part of the study was limited to educational developments in the teaching of science during the
20th century, in particular, the period from 1920 to 1958. The educational reforms brought about by foreign rulers during the colonial and World War Two period had a significant impact on the education system in Singapore and on the teaching of science. Therefore the focus of this part of the study was to describe and analyse the early development of an education system in Singapore with special reference to the development of the teaching of science.

The second aim was to develop an understanding of the teaching of science, from 1959 until recent times with special reference to the teaching of biology. During this period, globalization and foreign influences had a strong impact on the development of the nation’s education system. The impact and the subsequent reforms and policies that were introduced were described.

The third aim was to develop an understanding of the issues which are currently of concern to secondary school biology teachers and the perspectives they have regarding the teaching of biology in Singapore. This part of the study investigated the issues, challenges, and concerns that secondary school biology teachers in Singapore have as the country moves into a new era of science and technology.

2b. Research methods

The study is located in the interpretivist paradigm. This allows for an analysis of the conceptions of people in a social context. The interpretivist paradigm directs the researcher in understanding the meaning to human and social actions and through the study of this meaning, the researcher is able to understand what people understand concerning a phenomenon. The social theory of symbolic interactionism, which stresses the way individuals see, define, interpret and react to a certain situation is consistent with this research position.

Document analysis was used to address the first two research questions. Historical documents and recent documents of a primary source and secondary source were studied and analysed for the purpose of this research. Four semi-structured interviews were conducted with three teachers each time to address the third research question. The interpretivist paradigm was applied through the use of the concept of ‘perspectives.’ This concept involves the notions of
aims and intentions, significance, reasons and strategies. Data was analysed using the qualitative data analysis approach described by Miles and Huberman. The Miles and Huberman method describes a concurrent three-step process, namely, data reduction, data display and drawing and verifying conclusions and essentially involved five steps. The first step was to transcribe the interview recordings. Through the transcribing process, parts that were not relevant to the concerns of the teachers were removed. The second step was to identify the repeated concerns that were highlighted by the teachers. The third step was to categorize the data. This step highlighted certain issues that required further research from documentary data. As the first set of categories was determined, references back to the interview transcript were necessary. The fourth step involved highlighting the basic themes that emerged from the data. The fifth step was to categorize these themes into broader themes. This involved inference of the identified categories. Finally, four pattern codes - curriculum and syllabus, logistical constraints, assessments, and networking - emerged.

3. Summary of findings

Chapters Five, Six and Seven addressed the first, second and third aims of the study respectively. The summary of findings of each chapter is presented below.

3a. First research question

What is the historical background to the education system in Singapore from the colonial times (1920) until pre-independence period (1958) with special reference to the development of the teaching of science in secondary schools?

Chapter Five described and analyzed the early development of the education system in Singapore with special reference to the development of the teaching of science in secondary schools. This chapter outlined the changes to the education system in Singapore given its changing circumstances from colonialized nation to self-governance. Three significant stages of government and their influence on the developments of the educational system were described. They are the colonial times from 1920 to 1942, the Japanese rule from 1942 to 1945 and the pre-independence stage from 1946 to 1958.
The educational policies adopted in Singapore reflected an ‘education-economy’ relationship. This basically meant that the implementation of policies in education was designed to grow a skilled workforce in alignment with the demands of the economy. This was particularly important to Singapore due to its limited natural resources and its heavy reliance on its human workforce.

Initially, during the colonial period, there was no common curriculum or resources for schools in Singapore during the colonial times. The development of a uniform policy and system of procedures occurred only after the Second World War in the 1950s. The Japanese adopted a different approach towards education as compared to the colonial administration during the Japanese Occupation. There was an increased emphasis on vocational education and a focus on science and economics. Education was also used to build on industrial and technical development. In changing the emphasis of education in Singapore from that of being focused on academic subjects to a more technical emphasis, the Japanese administration had effectively related education to occupational opportunities. With a greater emphasis on science and technology in the curriculum and expansion of vocational and polytechnic education, Singapore was able to achieve economic success despite its limited natural resources. This continued on to the post-war period in Singapore. The underlying principle behind the education reform during the post-war period was to ensure full educational opportunities for all Singaporeans while progressing towards independence with racial unity and national loyalty.

The progression of the teaching of science in Singapore, from one which was strictly controlled to one that received a greater emphasis through the introduction of vocational and technical education, was observed during the period of 1920 to 1958. This paved the way for a greater emphasis on biology teaching, which was observed in the late 1950s.
3b. Second research question

What are the recent developments of the education system pertaining to the teaching of science in secondary schools in Singapore from 1959 to recent times, with special reference to the teaching of biology?

This research question sought to develop an understanding of the teaching of science, from 1959 until recent times with special reference to the teaching of biology. During this period, globalization and foreign influences had a strong impact on the development of the nation’s education system. Three different phases in its education structure from 1959 to 2011 were described, namely, the survival-driven phase, the efficiency-driven phase and the ability driven phase.

Singapore’s immediate emphasis upon its founding in 1819 was on trade and commerce and there was relatively little emphasis on science and technology. The political instability in Singapore following its founding contributed to the delay in the emphasis on the teaching of science. It was only after independence that the government of Singapore identified different vehicles to drive the socio-economic success of the country besides trade and commerce. This was when the teaching of science increased in importance. The findings from the three different phases are outlined below.

During the survival-driven phase, the educational reforms made set the building blocks for the survival of a united sovereign nation. There was an emphasis on the standardisation of opportunities and assessments during this time which contributed to a structured approach towards education. During the efficiency-driven phase, the focus was more pragmatic and policies and programmes were analysed for sustainability. More pathways and opportunities for the students were created to reduce the high attrition rate and to improve the quality of teaching and learning. The ability driven phase focused on educational transformations that were essential in developing a knowledge-based economy and knowledge-based workers. The Thinking Schools Learning Nation vision had a significant impact on the science curriculum and pedagogy. Supporting initiatives, such as the Teach Less, Learn More initiative and the
Information Technology Masterplan, had a direct impact on science teachers’ classroom practices.

3c. Third research question

What issues are currently of concern to secondary schools’ biology teachers and what perspectives do they have regarding the teaching of biology in Singapore secondary schools?

This research question developed an understanding of the issues which are currently of concern to secondary school biology teachers and the perspectives they have regarding the teaching of biology in Singapore. It provided insights to inform considerations for policy and further research, specifically in the teaching of secondary school biology, and the preparation and training of secondary school biology teachers. Data for this research question was collected using four semi-structured interviews at four randomly selected government secondary schools in Singapore. A total of twelve teachers were interviewed. Chapter Seven presented the concerns of teachers according to four broad themes, namely the issues with curriculum and syllabus, logistical constraints, assessments, and networking.

The teachers shared their concerns on the inclusion of molecular genetics and inquiry-based learning in the syllabus and the curriculum respectively. The findings from the interviews revealed that the teachers were concerned with the reduction of the classical biology topics in the syllabus. Some of them felt that the classical biology topics were essential for the understanding of biology as a subject. In addition, the teachers also expressed their struggles with incorporating inquiry-based learning in the curriculum. Their struggles revolved around their insufficient knowledge of inquiry-based approaches and the students’ reluctance to participate in inquiry-based lessons. This led to the concerns raised regarding insufficient time in completion of syllabus. In incorporating inquiry into the teaching of biology, time was identified by the teachers as insufficient, due to increased preparation and implementation time.

Further to this, the teachers shared concerns on the assessment processes in Singapore. The teachers shared opinions on formative and summative assessment. The emphasis on summative assessments has led to an increased amount of pressure on teachers and students.
However, the teachers felt insufficiently prepared to implement formative assessments. Lastly, concerns were presented regarding the insufficient networking platforms that shared useful and applicable strategies for biology teachers.

4. Propositions

Several propositions can be drawn from these research findings.

Table 7.1

Summary of propositions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Proposition No.</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Question One</td>
<td>Proposition One</td>
<td>The education-economy relationship was interpreted differently by each stage of governance in Singapore during 1920-1958. This relationship developed and changed over decades and provided Singapore with an excellent foundation for its successful education structure today.</td>
</tr>
<tr>
<td></td>
<td>Proposition Two</td>
<td>The emphasis on vocation and technical education during the Japanese Occupation was the beginning of the growth of the significance of science education in Singapore.</td>
</tr>
<tr>
<td>Research Question Two</td>
<td>Proposition One</td>
<td>The emphasis on national unity through education contributed greatly to Singapore progressing as an independent nation.</td>
</tr>
<tr>
<td></td>
<td>Proposition Two</td>
<td>The science culture that developed after independence was a result of a series of systems and frameworks that laid the foundation for a strong science culture in Singapore today.</td>
</tr>
<tr>
<td>Research Question Three</td>
<td>Proposition One</td>
<td>Struggles teachers face in effective syllabus delivery can be attributed to insufficient pedagogical and content knowledge.</td>
</tr>
<tr>
<td></td>
<td>Proposition Two</td>
<td>The lack of resources and support in curriculum implementation contribute to teachers’ struggle in implementing a new curriculum.</td>
</tr>
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</table>
4a. First research question

Proposition one

The education-economy relationship was interpreted differently by each stage of governance in Singapore during 1920-1958. This relationship developed and changed over decades and provided Singapore with an excellent foundation for its successful education structure today.

Education-economy relationship.

As mentioned in Chapter Five, education in Singapore acts as an instrument of its economic policies and nation-building and has been labelled as the education–economy nexus or relationship. The educational policies adopted in Singapore reflect this education-economy relationship from the colonial period, through to the postcolonial era and into the present. The implementation of policies in education and training was designed to grow a skilled workforce in alignment with the demands of the economy. This was particularly so in Singapore due to its limited natural resource and its heavy reliance on its human workforce. This allowed Singapore to achieve economic success despite its limited natural resources.

It was evident through the manner in which the colonial administration dealt with education, that there were no intentions to better the lives of the locals through higher education and consequently better jobs. Instead, they wanted the locals to be content with farming duties and work that would force them to remain under the power of the British. According to Steinburg (1971), the colonial administration was hesitant about allowing education to cause dissatisfaction among the locals in Singapore. For most of the 20th century, the colonial administration focused more on providing education for the development of a workforce meant for trade. The economy of Singapore during the 1920s to 1958 thrived based on the focus the colonial administration had on trade. Therefore as mentioned above, the education-economy relationship during the colonial administration focused on the development of a workforce trained in trade.
As mentioned above, the education-economy relationship changed according to the different stages of governance in Singapore. During the Japanese Occupation, the economy changed from one based on entrepot trade to an economy that needed more industrial workers. After World War Two, these workers provided the basis of a small skilled industrial workforce that supplied the growing manufacturing sector of Singapore’s economy. Education was also used to build on industrial and technical development. Mechanical and engineering skills were promoted during the Japanese Occupation and there was a significant growth in the number of vocational schools. The schools received steadily increasing attendance from boys 14 years old and above and these students found employment as civilian mechanics with the Navy, Army, and Air Forces. Within a year of conquering Singapore, the Japanese administration had set up six designated technical schools. Boys between 14 and 19 years of age were trained for the war-related jobs of aero-mechanics, mechanical engineers, electricians, mechanics and technicians.

The development of these vocational schools provided a significant foundation for Singapore’s education system. It was evident that the proliferation of technical schools and trade schools produced the nucleus of the skilled labour force that played an important role in the metamorphosis of post-war Singapore. The emphasis on vocational and technical education also signified an increase in emphasis on science education.

During the pre-independence period, the colonial administration made significant changes to the education system to match the increasing demand of a skilled workforce. Vocational and technical education increased in emphasis and this supported the industrialization of the Singapore economy. A polytechnic was established to address the technical labour shortage of the 1950s that came with the growth of manufacturing (Blackburn, 2017). The establishment of these educational institutions was an attempt by the colonial administration to decolonise Singapore by creating a foundation of industrial training that would allow the country to supplement its workforce for an industrialised nation.
Proposition two

The emphasis on vocational and technical education during the Japanese Occupation was the beginning of the growth of the significance of science education in Singapore.

The Japanese administration changed the perspective and mind-set of Singaporeans. This was especially significant because it changed the way Singaporeans approached the colonial administration in matters of legislation and education during the post-war period. Wilson (1973) concluded that education in Singapore during the period of the Japanese occupation cannot be considered in isolation. This is because the education system evolved greatly during the occupation, resulting in significant shifts in priorities and mind-set.

In changing the emphasis of education in Singapore from that of being focused on academics to a more technical emphasis, the Japanese administration had effectively related education to occupational opportunities. The development of these vocational schools stimulated the growth of the teaching of science in secondary schools in Singapore. From 1942 to 1959 vocational and technical education increased in emphasis and this supported the industrialization of the Singapore economy. A polytechnic was established to address the technical labour shortage of the 1950s that came with the growth of manufacturing.

4b. Second research question

Proposition one

The emphasis on national unity through education contributed greatly to Singapore progressing as an independent nation.

As Gopinathan pointed out during an interview conducted in 2014, the present model of Singapore’s education system draws its fundamental strengths and policies from its early years of nation-building. The Prime Minister of Singapore in 1965, Lee Kuan Yew reiterated the need and his desire to grow a multi-racial, multi-ethnic society in a democratic and independent nation.
The strength of the education system and economy in Singapore today can be attributed to this early strategy to ensure the education system worked on the basis of providing the appropriately skilled workers. After the Goh Keng Swee report in 1978, the educational reforms focused on ensuring the equal educational opportunities for all regardless of race and religion. The school curriculum was used to foster national unity by underscoring the ethnic-national identity for its citizens. Since self-governance in 1959, the government implemented ethics as a teaching subject in 1959, followed by civics in 1963. ‘Education for Living’ was also taught as a subject in 1973, followed by ‘Good Citizen’, and ‘Becoming and Becoming’ in the 1980s (Chew, 1998). These subjects promoted national unity and educated the students regarding their duties as good citizens. The civics and moral syllabus aim to “incorporate more concepts and contents that are relevant to meet the changing needs and future challenges of the nation” (Tan & Chew, 2005, p. 601). National Education was introduced in 1997 and it aimed to develop national cohesion in all Singaporeans. The subject of social studies was also used as a platform to emphasise knowledge and understanding of national issues pertaining to historical, political, economic and social development of Singapore. According to the syllabus, the aims are to enable students to understand the issues that affect the socio-economic development of Singapore to build and sustain a politically viable, socially cohesive and economically vibrant Singapore. Social studies also aim to develop citizens who have empathy towards others and who will participate responsibly and sensibly in a multi-ethnic, multi-cultural and multi-religious society.

**Proposition two**

The science culture that developed after independence was a result of a series of systems and frameworks that laid the foundation for a strong science culture in Singapore today.

In Singapore, education has consistently been the building block for economic and national development. As Singapore evolved from a labour-intensive manufacturing economy to a more capital and skill-intensive industry, the education system has been versatile enough to follow through with a consistent quality of education and the supply of specific skills needed to
maintain Singapore’s global competitiveness. Therefore, when Singapore reached an economic landscape demanding a knowledge-driven workforce, it was important that the education structure adapted accordingly. There was a greater emphasis on science and it was important to develop a science culture that would support this emphasis.

As mentioned in Chapter Six, science culture in this context refers to the attitudes of the public towards science and their general understanding of it (Solomon, 1996). Science culture developed through several policies such as compulsory education. Science societies were also established to create an outreach of science education to the masses. The establishment of these societies represents an important shift in the nation’s attitude towards science. Programmes and competitions were introduced during the 1980s as well. This was meant to create publicity for science education.

The development of the science culture in Singapore allowed the nation to embrace life sciences in the 1990s to allow Singapore to develop a workforce that was competitive with the growing change in the international landscape. The ability of a small nation to stay competitive in a world with constantly changing economic landscape can be attributed to a versatile and fluid education system. This versatile education system can be represented through the manner in which life sciences was adopted as one of Singapore’s economic pillars of growth.

4c. Third research question

Proposition one

Struggles teachers face in effective syllabus delivery can be attributed to insufficient pedagogical and content knowledge.

Pedagogical content knowledge is fundamental for the effective teaching of science. It includes an understanding of what makes the learning of specific topics easy or difficult. There are two similar interpretations of pedagogical content knowledge and they are described in Chapter Three. It has been shown by Randler and Bogner (2009), that the current teaching approaches in biology follow simplistic linear conceptions and students learn simplified
versions of the content that are not adequately representative of biological natural systems. As teachers, we are in a constant battle to resolve the dilemma between the simplicity of teaching and the complexity of the content. According to Wheelahan (2007), in an effort to simplify the content, it is presented to students as a one-dimensional knowledge structure which effectively denies students access to understanding. Therefore it is essential that the pedagogy used accurately reflects the intention of the curriculum. In the event it does not, students’ understanding is compromised.

The most significant change in biology content over the past century has been in molecular biology. Molecular biology can be described as a perspective that biologists use to explain the phenomena they are studying. There are several aspects of molecular biology that render it difficult to teach. Aside from being invisible, molecular biology is difficult to understand because there are several levels of organization that make the content complex and abstract. These were concerns that were shared by the teachers interviewed. They also expressed challenges in discovering an appropriate pedagogy that would engage the students and yet allow for effective content delivery. Rotbain et al. (2006) suggest viewing animations and using interactive simulations to aid in students’ understanding of abstract topics such as molecular biology. Such simulations can illustrate molecular interactions in terms of the random nature of collisions and the importance of direct binding and conformational changes.

In addition, teachers’ content knowledge of molecular biology was also highlighted as a concern for some of the teachers interviewed. They felt insufficiently prepared for the teaching of complex molecular biology content due to their lack of training.

Currently, in the National Institute of Education, curriculum studies are essential courses aimed to help pre-service teachers learn how to teach. However, an assumption is made during the training for pre-service teachers. This assumption is that the pre-service science teachers possess current and adequate subject matter mastery since the pre-requisite for admission into the program is a first degree in the relevant field. Therefore, the specific content of physics, chemistry, and biology is not taught to pre-service teachers during their training in
the National Institute of Education. This poses a challenge for biology teachers who have
majored in a first degree that does not essentially involve molecular biology content. This
challenge is reflected in the concerns of some of the teachers interviewed.

Proposition two

The lack of resources and support in curriculum implementation contribute to teachers’ struggle
in implementing a new curriculum.

Many of the teachers interviewed for the purpose of research question three have shared
challenges in incorporating the inquiry approach into their lessons. Teachers have been involved
in curriculum design and planning, as mentioned in Chapter One. However, during curriculum
implementation, teachers shared the sentiments of inadequate support. This results in the
enacted curriculum not reflecting the intended curriculum. The implementation of the
curriculum depends very much on the meanings teachers give to the curriculum or the
curriculum changes. These meanings determine the manner in which the curriculum is
implemented. Therefore it is essential that teachers give meaning to the curriculum changes.

Lee & Chue (2013) suggest testing the implementation of a new curriculum approach,
such as the inquiry approach, under ideal conditions. This could ensure more effective
incorporation of the approach into the curriculum. They also suggested monitoring
implementation issues with diligence. This would provide more details about the approach that
could possibly support teachers in their implementation and allow them to attach more meaning
to the curriculum change. Knowledge of the approaches to engage teachers in curriculum
implementation is important (Tan & Chew, 2014). When teachers gain the necessary experience
and knowledge to conduct an inquiry, the implementation will be more in alignment with the
intended curriculum.
5. Implications

The study provided the much-needed data to justify certain implications for the provision of quality teaching and learning of biology in Singapore as highlighted below.

- Development of an appropriately designed teacher training programme for the teaching of current content such as molecular genetics as well as training in the area of implementing formative assessment within the biology curriculum.
- Development of a platform for the sharing of best teaching practices within schools, with a similar profile of students, to allow for appropriate usage of pedagogical practices.

*Development of an appropriately designed teacher training programme for the teaching of current content such as molecular genetics as well as training in the area of implementing formative assessment.*

Biology teachers read different science majors in university, and some of them are not well equipped to teach the current topics such as molecular biology that have been recently introduced. Workshops and courses are provided by the Academy of Singapore Teachers as well as the National Institute of Education for in-service teachers. However, in service teachers struggled to find the time to attend the courses and workshops planned for them. This resulted in them feeling insufficiently prepared for the teaching of the molecular biology topics.

There is a centralized online platform known as TRAISI for all in-service teachers to view or sign up for courses or workshops. There are some professional development programmes on TRAISI to support teachers in their teaching of current content such as molecular genetics. However, these workshops are not scheduled on a regular basis and with a teacher’s heavy workload, it becomes increasingly difficult to attend these courses or workshops.

As education in Singapore embraces the inquiry approach, there has been a shift towards formative assessments. Formative assessment type questions have increased in
appearance in the national examinations. These were intended to aid learning and are closely associated with curriculum and pedagogy. Formative assessments are more open-ended and are considered to provide students with a platform to understand their weaknesses and strengths. There are some workshops or courses on the implementation of formative assessment. However once again, the teachers struggle with insufficient time to attend these workshops.

As mentioned in Chapter Seven, teachers struggle to adapt to implementing new curriculum approaches when they do not have sufficient knowledge on the subject matter. In addition, teachers’ interpretation and implementation of curriculum changes may not always be consistent with the intent and the expectations of the implementation body. To address these concerns, there could be online options for these courses where the teachers are able to assess and acquire the knowledge required in their own time. It may not be an optimum approach, but it will allow the teachers some insights into the basic requirement of the teaching of the content or the expected outcome for the mode of assessment.

The conduct of the courses or workshops could be provided at the school premises. This would allow the teachers an easier access to the information. It would also minimize disruption to the teachers’ classes. In managing these logistical constraints, teachers would acquire the required knowledge which allows for effective implementation in the classroom.

Further to this, recent biology content such as molecular biology could be taught during the teacher training programme. As mentioned earlier, science content is not explicitly covered in this programme due to the assumption that pre-service teachers would have acquired the first degree in science. If the content is taught during the teacher training programme, it may provide some foundation for beginning teachers in managing the content.

*Development of a platform for the sharing of best teaching practices in alignment with the profile of students from different schools.*

Currently, there are platforms for sharing of best teaching practices amongst the biology teachers in Singapore. The Biology Chapter, as mentioned in Chapter Six, is actively involved in providing a structured approach to guiding the teachers and providing a network for teachers.
However, the practices or the pedagogy shared by teachers may not suit the profile and the abilities of all students. Most of the time, the pedagogy shared is aimed at higher ability students. Teachers from schools with lower ability students are not able to apply a similar pedagogy to their lessons. A suggested approach could be to organize more sharing sessions based on the profile of the students. This could be determined by the academic standards of the school. The pedagogy or the approaches shared at these suggested platforms may prove to be more useful to teachers.

6. Recommendations for further research

There are three areas where further research would be helpful –

1. This study revealed that Singapore has moved to a new phase of education in response to the demands of the economy and the demand for a ‘thinking’ workforce. There have been numerous new initiatives such as the Singapore Teaching Practice which encourage a thinking curriculum. This new phase of education, a thinking-driven phase, may have a significant impact on the biology curriculum in secondary schools and is worth exploring.

2. Evidence from this study indicates a possible correlation between the implementation of a new approach in teaching and students’ attitudes towards the approach. During the implementation of the inquiry approach, one of the concerns highlighted during the interviews with the teachers was the students’ attitude and acceptance of the inquiry approach. The manner in which the students perceived the inquiry approach impeded the successful implementation of the approach.

The correlation between teachers’ attitudes, competencies, and perception of new approaches and the successful implementation of the approach has been extensively researched but not the students’ perception in the same manner.

3. This study revealed a lack of research into the accurate implementation and effectiveness of formative assessment on the biology or science curriculum in secondary schools in Singapore. Formative assessment on its own has been extensively researched. However,
there is a lack of research highlighting the implementation of formative assessment in the teaching of biology.
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