Incidental Learners:

Exploring primary school science teachers’ learning during the Science Enrichment Programmes at the Science Centre Singapore

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Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Savita Sharma 28/4/16
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ABSTRACT

Teacher learning is active, continuous and challenging. As there is growing and ever-broadening knowledge in science, teachers need continuous support to maintain best practices throughout their career. For teachers to perform their diverse and complex roles, they need relevant science learning experiences. This is especially the case for primary school teachers.

This study investigated whether and how primary school teachers in Singapore learn during Enrichment Programmes which are designed for primary school students, at Science Centre Singapore. The main focus of the study was to explore the nature of teachers’ constructed knowledge during the programmes, which are facilitated by three different dimensions of science communication. The method included a survey, interviews and observations.

Analysis of the data from quantitative and qualitative results enabled a description of teacher learning in the programmes designed and conducted for students. The results led to the construction of a teachers’ learning model. This model establishes that teachers learn through communicating in different roles during the programmes. Further reflection leads to useful integration of the knowledge gained, which then contributes to classroom practice. The programmes provide a unique space for enhancement of elements of the teachers’ professional knowledge landscape, which differs from the kind of professional development offered in programmes designed for teachers. Further research is required, however, to understand more about how Pedagogical Context Knowledge is informed by these different roles.
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Preamble

As a Science Educator for the past 22 years at the Science Centre Singapore, I have been conducting Science Enrichment Programmes for primary and secondary students.

These Programmes consist of a series of enrichment workshops that started in 1977, to complement formal science learning and teaching in schools. They include laboratory courses, lectures, demonstrations, science talks, gallery teaching, guided tours, mathematical problem-solving activities, observatory sessions and computer courses. Through these programmes, students’ interest and engagement through inquiry-based learning is guided through various experiments and hands-on activities – all with a goal of communicating scientific principles.

In my role as a science educator, I have observed the students and their teachers who accompany them to the Science Enrichment Programmes. I have observed the teachers talking to their students and taking part in the activities during the Science Enrichment Programmes, even though the programmes do not set out to target these teachers. Some teachers have anecdotally shared that they benefit from the Science Enrichment Programmes experience. This has led me to consider what the teachers do when they accompany their students for the Science Enrichment Programmes and what happens to the teachers when they are exposed to the same learning environment which is designed for their students. More importantly, I have thought about what happens after the programme, when the teachers return to their formal classroom teaching in the schools. These thoughts sparked the interest in me to find out if there is an impact of the Science Enrichment Programmes on the teachers, and this investigation is the subject of this thesis.
Chapter One

Introduction

Background to the Study

Teachers are the most important factor in student learning (National Research Council, 1996; 2007). They play a key role in each student’s learning process and no system of instruction can operate without skilful teachers (NRC, 2007, p.268). They are responsible for the subject matter that is taught, and how that content is taught in the classroom (Abell, 2007; King & Newmann, 2000). It is also important to note that “student learning depends on every teacher learning all the time” (Fullan, 2007, p.35). Access to new information creates an ever-broadening science knowledge base, which is reflected in new education methods that emphasise student-centered inquiry in classrooms. Therefore, teachers need to constantly learn new knowledge, including science content and pedagogy and to keep up with best practice which will be different for different schooling levels (Ball & Forzani, 2009). Hence, the kind of education needed today requires teachers to be high-level knowledge workers, who constantly advance their own professional knowledge as well as that of their profession (Boaaventura & Faria, 2015). Darling-Hammond and Bransford (2005) emphasised that teacher education programmes should prepare them to develop contexts that will support the learning of all of their students. More specifically, the NRC (1996) recognises that learning experiences for teachers of science must “address teachers’ needs as learners and build on their current knowledge of science content, teaching, and learning… with real situations and expand their knowledge and skills in appropriate contexts” (p.62).
Teaching science in primary school\(^1\) can be especially challenging as teachers have to focus on several subjects and may have limited knowledge of science subject matter. This is a grave concern, since primary education is intended to set the foundation for science education at high school and for lifelong learning. Moreover, science in primary school is expected to build young students’ innate curiosity about the natural world and lead to scientific interest in later years. However, primary school teachers, typically, lack a formal educational background in science that may result in a lack of confidence to teach it (see Kenny, 2010). Many primary school teachers feel unprepared to teach science even though they are accountable for their students’ performance in this subject (Madden & Wiebe, 2015). This can lead to limited teaching of science in primary schools (Lake, 2005), and has also led to calls for more science content to be included in teacher training and professional development (Desimone, 2009).

Professional development\(^2\) is currently the main method of fulfilling the high demand for effective teachers in education systems in many countries (Darling-Hammond, 2005). Professional development is offered in both formal and informal settings, and can take the form of training courses, workshops and seminars that may focus on

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\(^1\)Primary School: A period of formal education starting after pre-school and continuing until secondary school (high school). Primary schools in Singapore are mainly classified as Government or Government-aided schools. Primary education (mostly referred to elementary schools) in Singapore consists of primary 1-6. The overall aim of primary education is to give students a good grasp of English language, mother tongue and mathematics (MOE, 2015) \(\text{http://www.moe.gov.sg/education/primary/}\)

\(^2\)Professional Development: According to Feiman-Nemser (2001), “professional development means transformations in teacher’s knowledge, understandings, skills, and commitments, in what they know and what they are able to do in their individual practice as well as in their shared responsibilities” (p.1038). According to Lowden (2005), “professional development is to provide opportunities for teachers to learn and grow within the profession, thereby making an impact on student learning”(p.8). Guskey (2000) defined professional development those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might, in turn, improve the learning of students (p.16).
subject knowledge, pedagogy, classroom management skills, and teacher networks. Research suggests, however, that teachers learn more effectively when activities require them to be engaged with materials of practice which are school-based and are integrated into their daily teaching work (Wei, Darling-Hammond, Andree, Richardson & Orphanos, 2009). Nevertheless, little is known about professional development that occurs in informal environments.

Learning that takes place outside the formal school environment is referred to as informal\(^3\) or non-formal learning\(^4\). Informal and non-formal learning have been the subject of educational and policy discussions for several years (Colley, Hodkinson & Malcolm, 2003). Literature on informal science learning (see, for example, NRC, 2009; Tal, 2012) indicates that many benefits for students can be derived from such places. Recently, Yeo (2014) commented that learning outcomes derived from informal learning experiences are similar to those desired in formal science learning but they continue to be a challenge to achieve. Despite the benefits of learning in informal

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\(^3\)Informal Learning: Informal learning includes all forms of learning that take place outside the traditional, formal science classroom (Yeo, 2014). Many researchers and practitioners in the museums, science centres and other educational fields refer to informal learning that occurs out of school-settings, in contrast to the more “formal setting to the classroom” (Gutwill & Allen 2012; Leinhardt & Knutson 2004; Phillips, Finkelstein & Weaver-Freichs, 2007; Tal & Morag 2007). Informal Learning as described by Stocklmayer, Rennie and Gilbert (2010) includes conscious and unconscious forms of learning. Such learning occurs outside formalised educational institutions, “in most cases it is unplanned, casual, implicit, and unintentional, at least not institutionally organised”. These environments include museums, science centres, aquariums, zoos and botanical gardens. Some researchers describe these environments as “free choice” (Falk and Dierking, 1992).

\(^4\)Non-formal Learning: Refers to purposeful teacher-planned learning activities that support the formal learning in the classroom but are not taught by the teacher or evaluated, such as learning on field trips at a science museum. According to Eshach (2007), learning in non-formal settings is structured and tutor or guide-led but more flexible than formal learning. There are often unintended outcomes associated with informal, and perhaps non-formal, learning and the social nature of activities plays a central role.
settings, such platforms are still relatively untapped by schools (p.238), and much remains to be explored about possible learning outcomes.

Faria, Chagas, Machado and Sousa (2012) stated that non-formal science institutions help to strengthen school science through the implementation of collaborative actions with schools or science teacher training institutions. Moreover, science museums and science centres\(^5\) can play an important role in the reform of science education by creating a more interested and receptive audience for future and lifelong science learning. Rich experiences from the outside world can compensate for some of the inadequacies of formal learning\(^6\) (Lucas 1983, p.1) as the attributes and processes are different from learning in schools (Phillips et al., 2007, p.1489). Falk and Dierking (2000) argue that “learning is both an individual and group experience” (p.43). “Verbal and non-verbal social interaction play a critical role in supporting learning” in informal institutions (Fenichel & Schweingruber, 2010, p.14). The influence of informal science education has long been acknowledged as an effective tool to enhance the formal methods of classroom teaching and learning (see Price & Hein, 1991).

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\(^5\)Science Centre/ Science Museums: Science centres and science museums are popular informal learning spaces. According to Salmi (2012), a science centre is a learning laboratory where visitors can learn scientific ideas by themselves using interactive exhibits and it is a place where informal education can be studied in an open learning environment (p.45).

Dairianathan and Lim (2014) stated that “science centres and science museums are considered leisure attractions or edutainment centres that provide support for students, teachers and families with opportunities to experience and understand science in an enjoyable setting” (p. 251). In the most general sense, science centres can be defined as places where visitors are connected with science, given curiosity, wonder, encouragement, and first-hand experiences (Association of Science-Technology Centres, ASTC). One of the most distinguished characteristic of science centres is their ability to mix learning and entertainment (Weitze, 2003) by allowing visitors to touch, play, and experiment with the exhibits (Quin, 1990).

\(^6\)Formal Learning: Activities or experiences with the objective of acquisition of knowledge from recognised and certified learning institution such as schools, colleges, polytechnics, vocational institutions and universities. Such instruction is generally considered to be compulsory, structured, sequenced and teacher-led, subject to assessment and certification of learning gained.
Holliday, Lederman, and Lederman (2014) explained that teachers in informal environments learn while talking to each other and, in a science centre, when they engage themselves with exhibits. Moreover, teachers will not only attempt to make sense of the science content for themselves but for their students as well. It was revealed that their visits helped them to “constantly try to figure out how to best present the information to students and how to use the exhibit texts or associated guidebooks/worksheets for their classroom visits” (p.950). However, it is not clear from the literature how teachers communicate and connect these experiences back to their classrooms.

**The Singapore Context**

The Ministry of Education (MOE) in Singapore is committed to a holistic education and requires teachers to prepare students for the challenges of their future life. Formal schooling in Singapore begins at the age of seven, and more than half a million students are enrolled in public schools largely funded by the government. In total, there are about 173 primary schools in Singapore (Poon, 2014, p.5). Primary education has been compulsory under the Compulsory Education Act since 2003. Primary education consists of a four-year foundation stage (Primary 1 to 4) and a two-year orientation stage (Primary 5 to 6). Science, as a subject, is introduced from Primary 3 onwards. Students are placed in classes with one teacher and may be assisted by specialist teachers in certain subjects, such as music, physical education, and in some instances, science. The class size is generally 30 for students in Primary 1 and 2 and about 40 in Primary 3 to 6 (Poon, 2014). In most primary schools, between 1.5 and 2.5 hours per week are devoted to science lessons (Tan & Tan, 2014). At the end of Primary school (at Primary 6), all students sit for the Primary School Leaving Examination (PSLE) in
four subjects namely English language, mother tongue, mathematics and science. This reflects the importance of science in Primary education, even though the learning of science begins at Primary 3 (Poon, 2014, p.5).

According to Yeow (1982) as cited in Poon (2014), science teaching in Singapore first became part of the formal Primary school curriculum in 1959, with a recommended syllabus and curriculum time (of 1.25 hours per week for Primary 1-3 and 2.25 hours per week for Primary 4-6). The aim of teaching science was to “(a) create interest in nature and its working; (b) encourage the natural curiosity of children and to inculcate a spirit of inquiry; (c) train children to observe, to experiment and to seek further knowledge” (p.160). In 1963 a damning report by the Commission of Inquiry into Education in Singapore, stated that science teaching consisted of verbal dictation of notes by teachers and that lack of facilities and equipment resulted in limited access to laboratory activities for students (Mackie, 1971, cited in Poon, 2014). At that time, there were not enough science teachers and a large number of primary teachers did not have adequate training in science. Also Cahill (1984) noted that science was taught in English and other vernacular languages of Chinese, Malay and Tamil and it was only by the end of 1978 that all science was taught in English.

When Singapore became independent in 1965, it was an impoverished country where many children did not attend school at all. The goal at that point was to establish universal primary education as soon as possible, so there was mass recruitment of teachers, crash course programmes, and a dilution of standards (Gopinathan, Wong, & Tang, 2008; Stewart, 2010, p.92). The Institute for Education was established in 1973 that offered specialised training in the teaching of science and professional development.
for teachers (Stewart, 2010). In the 1990s, another broad set of changes was made to increase the quality and attractiveness of the teaching profession. As part of this, the Institute of Education became the National Institute of Education (NIE), an autonomous unit of Nanyang Technological University (NTU). New degrees were introduced, and research to improve teaching and inform policy development became a more significant part of NIE’s mission (Stewart, 2010. p.92). Many professional organisations worked in partnership with Ministry of Education (MOE) and NIE to upgrade the skills of science teaching in schools.

In Singapore, out-of-school learning⁷ has been emphasised as one of the means to “develop a strong science culture that would help … [the] people to be more receptive towards the potential of science and technology-driven socio-economic development” (Teo, 2000 p.1). Out-of-school learning experiences that are meant to complement formal learning usually come in the guise of enrichment activities (Caleon & Subramaniam, 2003, p.511). Accordingly, several institutions that serve as informal learning venues supplement formal science learning in Singapore (Caleon & Subramaniam, 2005). The contents of several of these Science Enrichment Programmes have been aligned with the formal school science curriculum, so that school groups have a reason to visit these institutions.

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⁷Out-of-School Learning: A generic term to encompass all forms of education where knowledge is acquired through experiences outside the classroom context. According to Knapp (2006) it is “The instructional use of natural and built areas to meet student learning objectives in a variety of subject-matter disciplines through direct experiences” (p.1831). Museums and science centres are out of school learning environments Eshach (2007, p.171). Learning in out-of-school settings is often referred to as informal learning by Phillips et al., (2007, p.1489). Yeo (2014, p.239) stated that out-of-classroom activities are often considered by teachers and students as enrichment, an add-on to what is learnt in the classroom and not crucial to what is stipulated in the science curriculum.
One such institution is the Science Centre Singapore, which has been reported to be effective in enhancing science interest and achievements among school students (Lam-Kan, 1985). For this reason, Science Centre Singapore is utilised to serve an adjunct for the schools and to help in enriching the school curriculum (Subramaniam, 2003; Tan & Subramaniam, 2003).

The Science Centre Singapore is a non-formal (statutory) educational institution under the purview of the MOE. According to Dairianathan and Lim (2014) “the Science Centre Singapore learning experiences, variously called informal learning, non-formal learning, free choice learning or out-of-school learning have been compared against classroom learning. The types of programmes range from field trips, complementary enrichment laboratory programmes, school camps, community or science-based service learning opportunities for students to professional development for teachers and building resources for use in the classroom. Such programmes offer an alternative (and usually) complementary way of learning science” (p.251). (Also see Appendices 1).

Out of a vast range of programmes, primary school students and their accompanying teachers are the main visitor group to the Science Centre Singapore. Science Enrichment Programmes are, as was mentioned in the preamble to this thesis, a popular out of school learning experience for this particular visitor group. These programmes provide opportunities for students to learn about science beyond the confines of the classroom, in a fun and enjoyable way. They cover topics from biology, ecology, physics, chemistry, robotics, astronomy, and extend everyday subjects such as kitchen science. The programmes are specially designed to connect to what teachers are
required to teach in the classroom and they aim to complement and support the school’s science and mathematics curricula.

The Science Enrichment Programmes are conducted in specialized locations by qualified science educators\textsuperscript{8} at the Science Centre Singapore. Out of school experiences such as enrichment programmes have been found to provide meaningful learning to students. Their impacts include cognitive, affective and social aspects of learning. An important element of this learning is described by Marsick and Watkins (1990) as “incidental learning\textsuperscript{9}”; i.e. "learning outside of formally structured, institutionally sponsored, classroom-based activities" (pp.6-7). It is not clear from the literature, however, what teachers actually do in these informal learning settings for students, include identifying any teacher learning that takes place, and how teachers translate the experience back in the classroom. Price and Hein (1991) have suggested that informal learning settings designed for students can also provide opportunities for teachers to learn incidentally. It is implied that the opportunity to discuss ideas with students

\textsuperscript{8}Science Educator: The science educator is a term used for the person responsible for planning, researching, developing and communicating science concepts clearly to public, teachers and students through a series of conducting science enrichment programmes, exhibition tours and science demonstrations conducted in the science centre galleries and teaching venues. Mostly, science educators are subject expert and possess relevant degrees. They are selected with good communication and presentation skills. In this study, the term science educator is used to designate the person who conducts Science Enrichment Programmes who tends to have a varied science and teaching background.

\textsuperscript{9}Incidental Learning: The term ‘incidental learning’ is a sub-set of informal learning and is sometimes used interchangeably with informal learning. Marsick and Watkins (1990) used informal and incidental learning to distinguish between planned and unplanned learning. They described informal learning as experiential and non-institutional, and incidental learning as unintentional, a by-product of another activity. There is the potential for this type of learning to occur more often than formal learning. In this study, incidental learning or informal learning is used throughout for teachers learning during the science enrichment programmes when they accompany their students.
outside the classroom may contribute to teachers’ learning. The nature and the processes of this learning, however, remain undefined. The Singapore context provides an informal learning setting for teachers who accompany their students to the Science Enrichment Programmes: a setting which enables such learning to be examined.

**Statement of the Problem**

Thus little is known about the teachers who accompany their students to Science Enrichment Programmes at the Science Centre Singapore; in particular whether and how useful the Science Enrichment Programme experience is for the teachers. If there is a benefit to the teachers, then ways to improve their experience need to be explored. This thesis, therefore, sets out to describe the teacher experience in these Science Enrichment Programmes through the following overarching research question:

**Do primary school teachers learn from attending Science Enrichment Programmes designed for the students at the Science Centre Singapore? If so, what is the nature of their learning?**

The above research question was first explored through a pilot study, in order to gain an insight into the teachers’ learning in the Science Enrichment Programmes and to understand whether learning occurs. This exploratory pilot enabled further exploration of how this learning is facilitated, how teachers integrate this learning and whether it contributes to communication of science in the classroom. Accordingly, a set of two supplementary research questions was developed to obtain empirical evidence with which to answer the overarching research question above. These two supplementary research questions are listed below:
1. How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

2. How do teachers integrate that learning into their classroom practice?

Method

Three separate investigations were carried out to answer the two supplementary research questions in the present study. It was intended that each of these investigations would offer a unique perspective to the overarching research question. A descriptive account of the research methods is given in Chapter Three of this thesis.

A pilot survey was used to establish whether teachers learn in the Science Enrichment Programmes. This was intended to answer the overarching research question and establish, thereby, a basis to investigate answers for the two supplementary research questions. Investigations of the main study commenced after analysis of the pilot survey.

The first stage of the main study consisted of surveys of 120 primary school teachers who accompanied students to the three Science Enrichment Programmes selected for this study; viz. *Aquatic plants and animals, Diversity of cells,* and *Light.* The survey questions were framed to gain information about the teachers’ background, their purpose in visiting the science centre, the subjects they teach in the school, and their perceptions about possible learning in the Science Enrichment Programmes. Information from the survey was intended to help in designing questions for the next stage; i.e. interviews.
The second stage of the main study used the *Interviews about Instances* technique to explore teachers’ learning in the Science Enrichment Programmes. Sixty interviews were conducted with the teachers who participated in the surveys in Stage 1. Key learning points based on the teachers’ responses were identified from the interview data and used to design the observations that followed. In the final stage of the main study, observations of teachers attending nine Science Enrichment Programmes were carried using participant observation methods.

**Significance of the Study**

Overall, this study identifies an important place for incidental learning through explorations of teachers’ experiences in informal learning settings designed for students in the Science Enrichment Programmes at the Science Centre Singapore. This study is significant for three reasons.

First, this study is important for science centres, museums, schools and educationists in building and planning students’ and teachers’ education in an informal way. In addition, it will provide an insight into whether elements of formal and informal learning can be combined to produce a positive effect for the personal and professional development of teachers.

Second, it has the potential to support new and important ways of teacher learning in informal settings (besides professional development). This study has the potential to support new means of teacher learning development and to improve the practical experiences of in-service teachers. An advantage of this type of learning for the teachers
is that they learn with the students. The teachers and students are co-participants in the learning process.

Third, this study will identify how primary school teachers, both with and without science backgrounds, have the opportunity to explore new knowledge and improve their practical experiences in the Science Enrichment Programmes conducted for students. With a clear understanding of content knowledge, pedagogy and firsthand experience available in these programmes, teachers can explore, test, and refine their capabilities in informal settings. Above all, the study provides the basis for rethinking how informal learning experiences can be linked to school environments.

**Limitations of the Study**

This study has two limitations. First, this study is based on the findings of how teachers learn in Science Enrichment Programmes conducted for the primary school students at the Science Centre Singapore. One may argue that study did not focus on the teachers who did not come for such programmes or who may have had different out-of-school experiences.

Second, this study has not directly investigated the primary school teachers’ subsequent classroom practices. Although this is a limitation, their classroom practice was explored through teacher interviews. Their responses are described in this thesis.
Structure of the Thesis

This thesis comprises six chapters: Introduction (the present chapter), Background, Research Methods, Results, Discussion and Conclusions, followed by References and Appendices.

Chapter Two is a review of the literature pertaining to teachers’ learning and how it is related to science centres and museums, through the provision of field trips. It examines teachers’ roles in informal science experiences.

Chapter Three is a description of the research methods that have been used to investigate the research questions that are explored in this study. Each method is described, based on a grounded theory approach, to reveal the findings of the study.

Chapter Four describes the findings which were found from the study for each of the investigation stages.

Chapter Five is a discussion of the findings as they relate to the literature, and includes the interpretation of the findings in the form of construction of a teachers’ learning model.

Chapter Six, draws conclusions from the findings of this study, and offers recommendations for future research.

The next chapter provides the reader with relevant literature which defines the boundaries, scope and backdrop against which this thesis is presented.
Chapter Two

Literature Review

Introduction

Science learning is a complex activity that spans learning from formal institutions to informal environments and even across the myriad opportunities of learning that occur in people’s lives. Research in the field of science learning, especially informal science learning, is as exciting as it is challenging. Extensive research has been undertaken, within the contexts of informal environments such as science centres and science museums, to analyse how informal learning takes place and when it exactly occurs. In a policy statement on informal science education, Dierking, Falk, Rennie, Anderson and Ellenbogen (2003), discussed several aspects of meaningful learning which frame research in these areas. Recently, Stocklmayer et al., (2010) discussed the synergy between formal school science and the informal sector: how these sectors can enhance science education, and how learning is facilitated in these sectors for students at school. Research suggests that such synergy between the formal and informal sectors can be very effective in promoting engagement and learning. Bevan, Dillon, Hein, Macdonald, Michalchik, Miller, Root, Rudder, Xanthoudaki, and Yoon (2010) stated that:

no single institution, such as schools, afterschool or youth organizations, or science-rich cultural institutions, can achieve this vision acting alone. It will take a combination of resources, expertise, timeframes, and learning designs to support and expand science literacy in today's world, p.12).
Research indicates that one of the reasons behind the success of informal institutions is that they create environments facilitating social interaction and generate positive attitudes towards science and its learning (Salmi, 2003).

Formal science learning is the complement to informal science learning and vice versa. Learning taking place outside formal education and training institutions is often referred to as informal or non-formal learning. Informal and non-formal learning have been the subject of educational and policy discussions for several years (Colley, Hodkinson & Malcolm, 2003).

For the purposes of this study, the term ‘informal’ learning or education in science refers to the semi-structured learning opportunity that takes place out of school (e.g. in science centres, museums, zoos and botanical gardens). Unfortunately, in the literature, the terms ‘informal’ and ‘non-formal’ education are used interchangeably. However, both terms are used to describe an environment where learning is generally open-ended and learner-centred. According to Colardyn (2002):

The terms non-formal and informal learning are often used as synonyms …What the present definition of [non-formal and informal] really translates is the still limited knowledge and understanding of what exactly one is dealing with, how complex it is, how vast is the territory one is moving in. For the time being, the concept is accepted as such and it can be considered that non-formal and informal are frequently interchangeable. (p.5)

Such experiences have been viewed by many as less structured, non-assessed, learner-centered, learner-directed and open-ended with many possible outcomes. Learning is a life-long process that takes place continuously. Humans are born with an innate capacity
to learn, and as we grow we keep on learning. The learning process never ceases (Kalantzis & Cope, 2004).

People learn science from a variety of sources, in a range of different ways, and for different purposes and reasons (Mõistus, 2004; Wellington, 1990). Some people learn to obtain a qualification, others for self improvement. Wahl (2002) states that, “if we want to understand how the natural, physical and social world works, the best place to be is right in the middle of it, watching, smelling, touching, listening, doing, wondering” (p.18). Schugurensky (2000) reported that:

Learners can use a variety of sources for their learning, including books, newspapers, TV, the internet, museums, schools, universities, friends, relatives, and their own experience. (p.2)

However, learning cannot take place in isolation. It takes place when people engage with each other, interact with the natural world and move about in the world they have built. Through learning, people form new identities of themselves (Kelly, 2002), and view the world accordingly through their own eyes. It is human nature to learn, even in the absence of a formal education system or a fixed curriculum. Education is, however, different from everyday learning. It is deliberate, as learning is addressed in a relatively conscious and explicit way (Kalantzis & Cope, 2004).

As we grow, we need to go through a formal education system that takes place in schools. The structure of the school curriculum is developed carefully to match cognitive preparedness, spiralling upwards to more complex and abstract concepts (Dairianathan & Lim, 2014, p.252). Such structural elements are not present in edutainment attractions such as science centres. Schools, however, cannot provide all
the information, experience and learning needed for teachers and students. Students in schools usually learn from their text books and other sources such as the school library, computers, and perhaps some work in the school laboratory, but that is not sufficient. Formal-informal collaborations are considered more effective than either method alone. A Caise inquiry report found that the best way to learn and expand a commitment to a certain field is through the use of multiple settings and multiple time frames (Bevan et al., 2010). The key to successful learning in the formal sector, however, is the teacher.

**The Role of the Teacher**

The success of any educational reforms lie with the teacher in the classroom (Tan & Tan, 2014, p.72). Researchers, including Savolainen (2009), found that teachers are important and they play an essential role in quality of education. Teachers are critical in the education system because they have the greatest influence on student outcomes and achievement (Rowe, 2002). Teaching is one of the most important and challenging professions in society. Darling-Hammond (2006) stated that:

> The importance of powerful teaching is increasingly important in contemporary society. Standards of learning are higher than they have ever been before, as citizens and workers need greater knowledge to survive and succeed. Education is important for the success of both individuals and nations, and growing evidence demonstrates that among all educational resources-teachers’ abilities are especially crucial contributors to students learning. Furthermore, teachers need not only to be able keep order and provide useful information to the students but also to be effective in enabling a diverse group of students to learn ever more complex materials. (p.1)

“Teaching is a complex and unique profession and one in which teachers transform their subject matter knowledge into a form that students can understand and use” (Barrett, 2014, p.25). McKinsey and Company (2007) studied twenty-five of the world’s school systems, including ten top performers, to find out why some schools succeed where
others do not. In their report they suggested three important aspects to improve present school systems: (1) getting the right people to become teachers; (2) developing them into effective instructors; and (3) ensuring that the system is able to deliver the best possible instruction for every child (p.16). Thus, the importance of teacher quality in improving educational outcomes is uncontested. Recently, Boaventura and Faria (2015) stated that:

In order to promote a change of perspective in science education, teachers should develop teaching strategies of critical thinking, organise learning in challenging environments, give careful support to students for their self-regulation and learning, based on problem solving and decision making. (p.454)

To improve the quality in the education system, teachers also need to be able and have opportunities to work collaboratively with others in designing learning environments, addressing the learning needs of particular groups of students, developing themselves professionally, and teaching with others in team approaches (Schleicher, 2012). Indeed, a review of innovative learning environments at the International Summit on the Teaching Profession (OECD, 2012) concluded that successful teachers need the following:

- To be well-versed in the subjects they teach in order to be adept at using different methods and, if necessary: changing their approaches to optimise learning. This includes content-specific strategies and methods to teach specific content;
- To have a rich repertoire of teaching strategies, the ability to combine approaches, and the knowledge of how and when to use certain methods and strategies;
- To employ strategies which include direct, whole group teaching, guided discovery, group work, and the facilitation of self-study and individual discovery;
- To have a deep understanding of how learning happens, in general, and of individual students’ motivations, emotions and lives outside the classroom, in particular;
- To be able to work in highly collaborative ways, working with other teachers, professionals and para-professionals within the same organisation, or with individuals in other organizations, networks of professional communities and different partnership arrangements, which may include mentoring teachers;
- To acquire strong skills in technology and use of technology as an effective teaching tool;
- To develop a capacity to help design, lead, manage and plan learning environments in collaboration with others;
- To reflect on their practice in order to learn from their experiences (p.38).

The NRC (2007) report provides significant evidence that student learning can be harnessed when teachers are aware of students’ ways of thinking and their experience base, and when they provide challenging problems for students to engage in.

Teachers’ understanding of how students learn has important implications for how they structure learning experiences and make instructional decisions over time. Teachers, as instructional designers need to understand student learners to make good decisions about how to teach them. They need to understand what students do when they learn, as well as the types of experiences that produce engagement and conceptual understanding. They also need to know the unique qualities of their students and unique demands of particular group of their students in their classrooms. (p.301)
Although teachers spend much of their time with their students little is really known about what teachers do and learn when they are with their students. Margaret Spellings, U.S. Secretary of Education, in her report on teacher quality (2005) stated that there needs to be a focus on:

...the essential principles for building outstanding teacher preparation programs in the 21st century and ... on the critical teaching skills all teachers must learn. In particular, all teacher preparation programs must provide teachers with solid and current content knowledge and essential skills. These include the abilities to use research-based methods appropriate for their content expertise; to teach diverse learners and to teach in high-need schools; and to use data to make informed instructional decisions. Successful and promising strategies for promoting these skills include making teacher education a university-wide commitment; strengthening, broadening, and integrating field experience throughout the preparation program; strengthening partnerships; and creating quality mentoring and support programs (p.iii).

Kwakman (2003) states that teachers need to change from their traditional role of transmitting knowledge. Instead, teachers have to fulfil a new role by creating stimulating learning environments and by acting as facilitators in their students’ learning processes. However, it is critical that teachers take charge of their own learning and examine all the factors that potentially influence what goes on in the classroom (Alexander, 2004). What teachers need to know and are able to do is not a simple task. McDonald (1996) quoted in Darling-Hammond and Baratz-Snowden (2007, p.118) stated:

Real teaching happens within a wild triangle of relations-among teacher, students, subject-and the points of the triangle shift continually. What shall I teach amid all that I should teach? How can I grasp it myself so that my grasping might enable theirs? What are they thinking and feeling—toward me, toward each other, toward the thing that I am trying to teach? How near should I come, how far off should I stay? How much clutch, how much gas?
Modern developments in education demand that teachers learn how to use new knowledge, tools and new technologies in their teaching. Student learning, therefore, mostly depends on how we prepare and support teachers (Ball & Forzani, 2009).

Darling-Hammond (1998) stated that teachers must know what students know and believe about a topic and how learners are likely to "hook into" new ideas. Teachers must have knowledge about the various ways students learn and be able to use different strategies to teach these diversities; they must consider these approaches in the evaluation and assessment of student knowledge. Teachers need pedagogical approaches to their subjects that they can use to meet the individual needs of diverse groups of students (Vavrus, Thomas & Bartlett, 2011). Byrne (1983) stated:

Teacher's knowledge provides the basis for his or her effectiveness, the most relevant knowledge will be that which concerns the particular topic being taught and the relevant pedagogical strategies for teaching it to the particular types of pupils to whom it will be taught. If the teacher is to teach fractions, then it is knowledge of fractions and perhaps of closely associated topics which is of major importance.... Similarly, knowledge of teaching strategies relevant to teaching fractions will be important. (p.14)

Learning in schools is fragmented and connections are not always made from teachers’ in-service learning to real classroom circumstances. Teachers need to be able to inquire sensitively, listen carefully, and look thoughtfully at student work, as well as to structure situations in which students write and talk about their experiences. As suggested by Darling-Hammond (1998):

Teachers learn best by studying, doing, and reflecting; by collaborating with other teachers; by looking closely at students and their work; and by sharing what they see. This kind of learning cannot be divorced from practice or in school classrooms divorced from knowledge about how to interpret practice. (p.8)
Recently, Opfer and Pedder (2011) cited in Barrett (2014, p.25) synthesised through a comprehensive literature review that it is important for teachers’ learning that they have “time to develop, absorb, discuss and practice new knowledge,” that it is important to connect professional development to the daily work of the teachers, and actively engage teachers in similar ways in which students should be engaged.

Cohen (1988) stated that “teaching is a practice of human improvement” (p.55), but the problem which arises is that the “practitioner depends on their clients to achieve any results” (p.57). The success of a teacher, therefore, depends mostly on the active cooperation of the students (Fenstermacher, 1990). It is important for the students to learn what the teacher is teaching and they should be willing to learn and understand. According to Dewey (1933) “there is the same exact equation between teaching and learning that there is between selling and buying” (as quoted in Jackson, 1986, p.81). Thus, it is very difficult for a teacher to work as a practitioner of human improvement. Dewey added that teachers spend much time in learning different skills, motivating students, understanding their psychology, their needs, their co-operation and still teachers are not certain of the outcome. Gilbert (1995) stated that students learn many things from their teachers. According to him, students even learn to interpret a teacher’s facial expressions, gaze, posture, smile, anger and body movements. These provide students with important information about their teacher’s emotional state and attitudes towards the students.

Stiegelbauer (1992) emphasised that “it is the responsibility of a teacher to lay strong foundations, create positive learning environments and experiences to provide the basis for future learning, or a positive attitude about learning” (p.24). Teaching is not just a
job, it is more than that. It is a means of passing knowledge or information from generation to generation. Without this there would be no progress. Teaching is a partnership with students, in which the teacher is not only a source of knowledge, but someone who will listen to what students have to say and incorporate this into useful learning experiences. Effective school learning requires good teaching, and good teaching requires good professionals who exercise judgement in constructing the education of their students. Yager (2005) states that:

Teachers are portrayed less as technicians (factory workers) and more as intellectual, reflective practitioners (professionals). Teachers are viewed (by the [NRC] Standards) less as consumers and more as providers of knowledge concerning teaching. Teachers are portrayed less as followers and more as leaders. They are seen less as persons housed in a classroom and more as a member of a professional community. The teacher is not seen as "the target" for change, but as a source and facilitator of change (pp.17-18).

In 1987 the National Board for Professional Teaching Standards (NBPTS) was established in the U.S. for the purpose of strengthening the teaching profession. The NBPTS (2006) outlined what teachers should know and need to do, in order to improve student learning and be able to teach diverse student populations. The following points were presented by the NBPTS:

- Teachers are committed to students and their learning;
- Teachers know the subjects they are teaching and how to teach those subjects to students;
- Teachers are responsible for managing and monitoring student learning;
- Teachers think systematically about their practice and learn from experience;
- Teachers are members of learning communities.

All of these attributes apply to science teachers.
The Role of Teachers in Students’ Achievement in Science

Goodrum and Rennie (2007) stated that “the teacher is a critical factor in determining students’ interest and motivation to learn science because it is the teacher who implements the science curriculum” (p.18). Teachers, therefore, need to have a clear purpose of what they hope their students will learn. In order to do this, they need to have a clear personal idea of what they believe to be knowledge-worth learning and the nature of science itself (Deborah, 2006, p.51).

Science teachers have to keep themselves up-to-date because they are in position to motivate and capture students’ interest in the sciences (Behrendt & Franklin, 2014, p.235). According to Wei, et al., (2009), in order to have a new generation with higher order thinking and skills, we need teachers who have higher order thinking skills and a deep knowledge of content. Recently, Zhai and Tan (2015) stated that:

Science learning is enacted in classrooms largely through the interactions between teachers-students, students-students, student-materials, and teachers-materials. In an elementary science classroom, the teacher is often perceived to be the authoritative figure to provide the direction for learning. As such, the roles played by teachers in elementary science classrooms are instrumental in shaping students’ experiences of science learning. (p.1)

Zhai and Tan (2015) explained that teachers’ roles are not fixed. Moreover, teachers’ roles depend on certain factors such as nature of the tasks, type of students, and availability of time and resources in the classroom. The researchers examined the classroom practice of three elementary teachers in Singapore to illustrate how learning of science is made possible through teachers shuttling between different roles to meet the complexities and changing demands of science as inquiry. They showed that teachers shuttle between four key roles to enable student learning science. These include
(1) dispenser of knowledge (giver); (2) mentor of learning (advisor); (3) monitor of students’ activities (police); and (4) partner in inquiry (co-learner) (p.1). They found that teachers’ roles in the classroom had implications for the practice of science as inquiry in the classroom. However, the above study did not reveal how teachers learn from these different roles for their personal development.

Darling-Hammond and Baratz-Snowden (2005) emphasised earlier that “teachers must know the subject they will teach and understand how to organise the curriculum in light of both students’ needs and the schools’ learning objective.” (p.14). Also, as Jung (2005) pointed out, teachers are expected to facilitate learning to students and make learning meaningful to individual learners, rather than just providing knowledge within the four walls of schools. Teachers can facilitate and be able to assist students in exploring, modifying and developing their personal frameworks of understanding in order to incorporate the desired aspects of scientific understanding (Hodson 2014, p.2538-2539).

As students are expected to learn more complex and analytical skills in preparation for further education and work in the 21st century, teachers must learn to teach in ways that develop higher order thinking and performance for their classroom (Wei, et al., 2009). According to Fullan (1991) if we want to bring changes in learning there is a need to focus on teachers. According to Hattie (2003):

It is what teachers know, do and care about which is very powerful in the learning equation and it is the one source of variance that can be enhanced with the greatest potential of success. (p.9)
To this aim, teachers must create a learning environment for students and then actively monitor the students through various classroom assessment methods as they engage in investigations. In order for science to be meaningful in everyday life for students Sneider (2011) indicated that the most important single factor in engendering positive attitudes is a knowledgeable and enthusiastic teacher. Moreover, as Sneider (2011) explains, whether in formal or informal settings, knowledgeable and skilful teachers have tremendous power to get students interested in science (p.3). In addition, teachers who adapt teaching methods that succeed in tapping students’ personal interests and engaging them at a deeper level can be very effective in increasing the pool of scientifically interested learners (p.8). It is important to note that teachers can only achieve this if they are able to monitor the learning process and are able to know what sort of support the students need at a particular point. Darling-Hammond (2005) pointed out that new standards require a new kind of teaching, conducted by “teachers who understand learning as well as teaching, who can address students’ needs as well as the demands of their disciplines, and who can create bridges between students’ experiences and curriculum goals” (p.5). Teachers are not only expected to develop a list of strategies, they also need to monitor the growth and development of each individual student and adjust their teaching to the individual needs. The NRC (2007) state that demands for providing teachers with effective science instruction are immense:

…in order to create a successful science classroom, teachers need to modify and adapt curriculum materials so as to design instruction that is appropriate for a particular group of students at a particular time. Making these kinds of modifications to achieve effective instruction requires knowledge of science, knowledge of how students learn science, and knowledge of how to plan effective instruction. (p.344)

Teachers may well have insufficient knowledge in one or all of these areas and need on-going support to develop it.
Darling-Hammond (1997) stated that the number one factor in enhancing student learning is the capability of the teacher. Teachers who know their content area and also know the cognitive abilities of the students are able to be more effective in structuring lessons for students. Several other researchers share the same belief: that quality interaction between the teacher and student is very important for student learning (Hill & Hawk, 2000; Dean, 1999; Gipps, 1994). Doyle (1987) also shared this view much earlier and stated that:

A teacher promotes student learning by being active in planning and organising her/his teaching, explaining to students what they are to learn, arranging occasions for guided practise, monitoring progress, providing feedback and otherwise helping students understand and accomplish work (pp.93-96).

Campbell, McNamara, and Gilroy (2004) indicated that teachers are responsible for maintaining high quality standards and increasing the achievement of students. Several recent studies have also demonstrated that the achievement of students is highly correlated to the quality of teachers (Collinson & Cook, 2000; Meister, 2010; Opfer & Pedder, 2011). Therefore, teachers are the most important agents in shaping education for students and in bringing about change and innovation in educational practices (Bakkenes, Vermunt, & Wubbels, 2010).

Not only what students learn but what teachers teach depends on the active participation and co-operation of the students (Labaree, 2000). Science teachers teach in many different ways and use diverse strategies and tactics (Barnett & Hodson, 2001). Tobin (1990) described teachers as broadcasters, tour guides, entertainers, and gardeners. Teachers play many roles, depending on the situation. Each role a teacher plays inspires their students to learn something new (Tobin & LaMaster, 1992).
Research has shown that students who receive active instruction and work supervision from their teachers achieve better results than those students who spend most of their time working through curriculum materials on their own (Brophy & Good 1986). Sanders and Rivers (1996) used student achievement data for teachers in the State of Tennessee to find out how effective the teachers were. Based on the results, they found that students who were taught and guided by ‘effective’ teachers had better results than the students who were taught by ‘ineffective’ teachers. They also found out that in one year, the most effective teachers can boost the scores of their low-achieving students. Recent research (for example, Ripley, 2010) shows that students with an effective teacher can progress as much as two grade levels in one year, while those with an ineffective teacher progress half a grade level or less on tests of academic achievement.

The importance of interconnection between student learning and teacher learning was reiterated at Michigan state university by Feiman-Nemser (2001) who commented that:

> After decades of school reforms, a consensus is building that the quality of our nation’s schools depends on the quality of our nation’s teachers. Policy makers and educators are coming to see that what students learn is directly related to what and how teachers teach; and what and how teachers teach depends on the knowledge, skills and commitments they bring in their teaching and the opportunities they have to continue learning in and from their practice. (p.1013)

**In summary**, teachers are the key factor in education, in the challenging world, and the critical factor in students’ learning in science. They are the main source from which students acquire knowledge. What students learn is directly related to what and how teachers teach. It is indicated in the literature that teaching depends upon the active participation of students. Teachers must know what to teach, and how it is communicated to their students is critically important.
**Why Focus on Teacher Learning in science?**

It has been established that teachers are critical factors in the success of any education system (Gopinathan & Sharp, 2002). As their roles are dynamic (Zhai & Tan, 2015), teachers play a key role in students’ learning (Ball & Forzani, 2009; Gunning & Mensah, 2011). They are the most important factors in the success of reform-based science instruction (American Association for the Advancement of Science, 1993). U.S. National science education reforms emphasise the important role of teachers in creating and sustaining classroom conditions that provide all students with opportunities for learning science through inquiry (NRC, 1996, 2000). Teachers are important in teaching science because, it is the teacher’s task to assist in exploring, modifying and developing students personal frameworks of understanding in order to incorporate the desired aspects of scientific understanding (Hodson 2014, p.2539). The role of the teacher will depend to a large extent on the function he or she performs in different activities. For instance, Harris and Rooks (2010) stated that when teachers incorporate recommended reforms into their instruction, student learning improves. For that result, teachers are required to continuously learn, reflect upon and develop their knowledge and skills. They are challenged to develop new understandings, relationships and approaches to student learning every time they meet a new group of students (Vavrus et al., 2011). Unfortunately, however, teachers frequently tend to teach science as they themselves were taught, with a focus on “canonical science ideas, and very little else” (Tytler, 2007, p.57). Weiss, Banilower, McMahon, and Smith (2001) conducted a survey with science and mathematics teachers which revealed that classroom science instruction continues to be dominated by teacher-centered instruction, direct transmission of knowledge, and an overemphasis on rote memorization of content.
It is very important for teachers to continue to learn because they are the main sources from which students might acquire new, up to date knowledge. Education is, therefore, important not only for the students but for the teachers as well. Part of this learning is concerned with student attributes For example, as Darling-Hammond and Bransford (2005) stated:

To make good decisions, teachers must be aware of the many ways in which student learning can unfold in the context of development, learning differences, language and cultural influences, and individual temperaments, interests and approaches to learning (pp.1-2).

Furthermore, teachers adopting a student-centred approach must be adept in ‘knowing the developmental, cognitive, and learning styles of students and ensuring that instruction is well matched to each’ (Dix 2012, p.11). According to Dewey (1938) “books, especially textbooks, are the chief representatives of the lore and wisdom of the past, while teachers are the organs through which pupils are brought into effective connection with the material” (p.18).

Teachers learn continuously from their experiences in the classroom, their interactions with colleagues, and their professional development activities (NRC, 2007. pp.306-307). Well-designed opportunities for teacher learning can therefore, enhance experiences in the classroom. Such opportunities can enhance teachers’ capacity for continued learning and professional growth, and can in turn contribute to improvements in student learning.

**Pedagogical Content Knowledge and Pedagogical Context Knowledge**

Teachers need to possess both a good understanding of the subjects they teach and of the best ways to teach these subjects - what has been called ‘Pedagogical Content
Knowledge’. It can provide insights into the complexities of teaching and teachers. Shulman (1986, 1987) coined the phrase Pedagogical Content Knowledge (PCK) as one of the types of knowledge that teachers should possess. According to him, teachers do not only have to know and understand the subject matter knowledge, but they also must know how to teach that specific content effectively. PCK is an important part of a teacher’s knowledge base. PCK represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted and represented for instruction. Shulman (1986) defined PCK as:

…for the most regularly taught topics in one’s subject area,[PCK is] the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others. (p.9)

Appleton (2005) describes PCK as “the knowledge a teacher uses to construct and implement a science learning experience or series of science learning experiences” (p.35). All teachers know that what is taught is not the same as what is learnt by their students. As in all acts of communication, learners have to make sense of what they hear, see and read in terms of what they already know. Teachers can make this easier or more difficult for students by the way that messages are put together, and the way that students’ questions are elicited and answered (Shulman, 1986, p.28). However, promoting the learning and achievement of students is the main aim of school education and teachers’ teaching their students is the main way of achieving this. Teaching and learning are what ultimately make a difference in the mind of the learner, and thus affect knowledge, skills, attitudes and the capacity of students to contribute to contemporary societies (James & Pollard, 2006).
Barnett and Hodson (2001) differ from Shulman (1987) by not directly including context within the PCK framework. They instead coined the term *Pedagogical Context Knowledge*, as a means to indicate that good science teachers’ knowledge, actions, and thoughts are located in the finer points of everyday classroom experience. According to them:

The sources of this knowledge are both internal and external: internal sources include reflection on personal experiences of teaching, including feelings about the responses of students, parents, and other teachers to one’s actions; external sources include subject matter knowledge, government regulations, school policies, and the like. Interaction with other teachers at both formal and informal levels is both a source of pedagogical context knowledge and a stimulus for its further development (p.436).

The sources of this knowledge were explained as both internal, for example, reflection on teaching and external-subject matter knowledge and school policies. Within this pedagogical context knowledge framework, four knowledge areas were included: academic and research knowledge, professional knowledge, pedagogical content knowledge, and classroom knowledge.

Within this framework, there are three kinds of places where knowledge is acquired, constructed, rationalised and deployed: private, semi-private and public (Barnett & Hodson, 2001). Their notion of *Pedagogical Context Knowledge* involves two components of the teachers’ knowledge landscape.

- Societal knowledge landscape: All knowledge for effective functioning of society. This landscape is explored by teachers individually and sometimes collectively, they learn to view it from different vantage points.
- Educational knowledge landscape: All knowledge pertaining to educational matters (p.436).
PCK as introduced by Shulman (1986) had four important aspects: subject matter knowledge, pedagogical knowledge, classroom knowledge and student knowledge. It is important for teachers to know all four types of knowledge and how to integrate this knowledge in their teaching. PCK represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organised, adapted and represented for instruction. When Barnett and Hodson (2001) coined the term *Pedagogical Context Knowledge* they included academic and research knowledge, pedagogical content knowledge, professional knowledge and classroom knowledge. Many of these areas present problems for primary teachers.

However, the benefit of PCK is only seen when the teacher critically examines what, why and how they are teaching something and provide evidence of what learning has been achieved if they are to develop their PCK further (Deborah, 2006, p.54). Similarly, for primary school teachers PCK may be best achieved by supporting them with as they learn how to teach science in realistic learning situations (Howitt, 2007; Kenny, 2010).

**Problems faced by Primary Science Teachers**

A major problem which teachers face is that the educational system is rapidly and drastically changing. Science teaching can be a challenging job, especially for primary school teachers, as “novice and experienced teachers struggle to find time, resources, and confidence to weave science into a crowded curriculum” (Kenny, 2010; Kisiel, 2013, p.68). Research indicates that inadequate teacher background in science (Davis & Petish, 2005; Kenny, 2010; Palmer, 2001); and teaching facilities (Appleton, 2003) are obstacles to effective science teaching in primary schools. Recently, Madden and Wiebe (2015) cited Wilson, Floden, and Ferrini-Mundy (2002) who stated that
“teachers at the elementary level are typically generalists, as opposed to experts in a particular content area, and tend to have especially varied backgrounds, interests, and preparation. Many elementary teachers feel unprepared to teach science even though they are accountable for their students’ performance in science”. (p.392)

A study by Childs and McNicholl (2007) found that teachers’ limited subject-matter knowledge affects their ability to give appropriate and effective science teaching explanations in the classroom and that has a significant impact on their planning and teaching. Their results showed that, “regardless of teaching experience, limited and insecure subject content knowledge did indeed affect their pedagogical content knowledge, making it constrained and lacking in challenge for their students (p.1632). Similarly, a recent report on the status of elementary science education in California states that only few science teachers have science backgrounds and they receive little support once they are in the teaching profession (Dorph, Shields, Tiffany-Morales, Hartry & McCaffrey, 2011). Effective science teaching requires adequate time. This in turn leads to limited teaching of science in primary schools (Lake, 2005).

Due to the structure of most primary schools, primary school teachers have to teach not only science, but other subjects, including language, arts, mathematics and social studies (Davis & Smithey, 2009). Within the subject of science, primary science teachers face further challenges, since at the primary level teachers are responsible for life science, physical science and earth science. They are, therefore, expected to teach all these subjects through engagement in authentic scientific practice (Davis & Petish, 2005). The problems have been identified for many decades. As far back as 1990, Tilgner said that over half of primary science teachers placed science fourth or fifth out
of the five subjects, in terms of the time they spent to teach it. Twenty-five percent indicated that they did not spend time teaching science at all, while the remaining seventy five percent spend less than two hours a week on science teaching. It is very difficult for primary teachers to focus on so many subjects. This view was also supported by Chris (1990) who commented as follows:

Most primary teachers are not science specialists and they feel intimidated at the prospect of introducing a subject with which they are not at ease. (p.264)

More recently, in Making Science Make Sense, the Bayer Corporation (2004) reported that primary science is taught less often than other subjects at primary level. Their report also added that teachers are not well prepared to teach science and wish they had more science teaching preparation (see also, Kenny, 2010). It appears that not very much has changed over the intervening twenty five years.

Since primary teachers typically lack a formal educational background in science, this has led to calls for more science content to be included in teachers’ professional development (Howitt, 2007). Many researchers (see, for example, Appleton, 2002; Appleton, 2003; Ferry, 1995; Fullan & Miles, 1992; Spillane, 1999) have reflected that pre-service teachers should be provided with positive teaching instructions in science to motivate them to continue to learn science and also increase their background knowledge. A serious challenge for elementary teachers is thus associated with their limited knowledge of subject matter (Anderson & Mitcher, 1994), and many teachers are poor in science content generally (Appleton, 2005; Tolman, & Campbell 1991). Studies by researchers Gabel, Samuel, and Hunn (1987), and Ginns and Watters (1995), indicated that a majority of primary science teachers show perceptual understanding rather than conceptual understanding of science concepts. Valanides (2000) reported
that when teachers were less knowledgeable in their subject content they were likely to rely upon low-level questions and give students fewer opportunities to speak.

Keys (2005) found that primary school teachers also have inadequate science resources and insufficient time for preparation. He added that these factors limit the quality and quantity of science teaching and learning in their classrooms. Some teachers depend on textbooks, which tends to limit the range of teaching strategies employed by those teachers (Tobin, Tippins & Gallard, 1994). According to other researchers (see, Keys, 2005; Goodrum, Hackling & Rennie, 2001; Lumpe, Haney & Czerniak, 2000) the content driven, transmission approaches to teaching are easier to prepare and deliver, while preparation and delivery of student-centred approaches is considered too time consuming.

In summary, teaching in primary school can be a challenging job. Teachers have to focus on many subjects and may have limited knowledge of subject matter. Most teachers are not trained or qualified in science, they come from different education backgrounds but have to teach science. They often lack strong understanding of science and often have few or negative science experiences. They are not confident to teach science. Primary science is therefore, taught less often than other subjects at primary level. Primary school teachers need help to acquire skills, knowledge and mastery of science in order to teach it well. This requires professional development.

Professional Development of Science Teachers

Before 1900, most educators viewed science as body of knowledge and they imparted this knowledge by direct transmission of information; emphasis was not given
to hands-on activities (Olson & Loucks-Horsley, 2000). At that time, students were not involved actively in the learning, they were passive listeners. Later in 1910, John Dewey, while addressing the American Association for the Advancement of Science, contended that science teaching gave too much emphasis to the learner gathering information and not enough to science as a way of thinking and an attitude of mind.

Concern about teachers’ ability to effectively teach science became especially intense after the successful launch of the Soviet satellite Sputnik in 1957. That launch caused great concern in the U.S. about elementary students’ inability to understand and apply scientific knowledge and led to great criticism of education at all levels and science disciplines in particular.

An important development since the mid twentieth century has been inquiry-based professional development opportunities for teachers (Kazempour, 2009). This was seen as an important contributing factor to the implementation of inquiry-based instruction in classrooms. According to Feiman-Nemser (2001) this type of professional development can be described as:

...actual learning opportunities which teachers engage in-their time and place, content and pedagogy, sponsorship and purpose. Professional development also refers to the learning that may occur when teachers participate in those activities. From this perspective, professional development means transformations in teachers’ knowledge, understandings, skills, and commitments, in what they know and what they are able to do in their individual practice as well as in their shared responsibilities (p.1038).

NRC (1996) stated that “the conventional view of professional development for teachers needs to be shifted from technical training for specific skills to opportunities for intellectual professional growth” (p.58). It is crucial for teachers to attend personal and
professional growth, job security and a career path to improve themselves, their schools and their students (Abdal-Haqq, 1996). According to Garet, Porter, Desimone, Birman, and Yoon (2001), if students need to achieve high standards, teachers will have to help them. Teachers are at the centre of the success of reform and they must implement the demands of high standards in the classroom (Cuban, 1990). Thus the success of education depends on the quality and effectiveness of teachers. However, this vision requires changes in classroom practice (Fullan & Miles, 1992; Spillane, 1999). According to Darling-Hammond and McLaughlin (1995), teachers have to change their approach to teaching and learning. Teachers should place more emphasis on understanding the subject matter they teach, and how students learn these subjects. The continuous deepening of knowledge, subject matter and skills are an integral part of any profession. Darling-Hammond (1997) recommended that future teachers have more rigorous preparation and more experiences to enable them to cope with the increasing complexity, challenges and diversity of current schools and classrooms and hence, they will have more opportunities to develop themselves professionally. To prepare students for the 21st century, it was said that it is critical that all students have sufficient knowledge of and skills in science. Studies suggested that high-quality teaching can make a significant difference in student learning. The National Science Teachers Association (NSTA, 2006) believed a high-quality science teacher workforce requires meaningful, ongoing professional development.

Teachers can undergo professional development in diverse places. Schools and informal science institutions both contribute to the improvement of science learning and teaching. Professional development takes place in the form of workshops, seminars, conferences, talks or courses offered through individual partnerships with provider
institutions. Some studies, however, describe this professional development as a way to inform teachers of available informal resources that are available at these institutions and to promote the institution itself (Chin, 2004; Melber & Cox-Peterson, 2005). Mundrey, Spector and Loucks-Horsley (1999) pointed out that teacher learning should be conceptualised as a career-long venture and might be best served by a field of professional development that is related to content and pedagogical needs of teachers from pre-service throughout their career. They added that professional development training sessions held outside the school are more effective and must be regularly attended by teachers. According to the U.S. NRC (1996) at that time:

All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry. (p.59)

These views have been reinforced since this time. To achieve the goal of providing professional development for teachers throughout their careers, professional development programs should incorporate the following guiding principles (Loucks-Horsley, Love, Stiles, Mundry, and Hewson 2003; Elmore 2002; Gess-Newsome 2001; Darling-Hammond and Sykes 1999):

- Professional development must help teachers build content and pedagogical content knowledge and examine their practice. It must provide opportunities for teachers to learn science as it should be taught to students, in order to help them recognize and refine their content understanding that supports teaching practice;

- Professional development programs should support teachers in leadership roles and enable them to go beyond fragmented knowledge they possess to more in-depth knowledge;
• Professional development programs should be based on student learning needs and should help science educators address difficulties students have with subject-matter knowledge and skills;

• Professional development programs should be based on the needs of science educators both as individuals and members of collaborative groups who are involved in the program;

• To best serve all students as they learn science, professional development should engage science educators in transformative learning experiences that confront deeply held beliefs, knowledge, and habits of practice;

• Professional development should be integrated and coordinated with other initiatives in schools and embedded in curriculum, instruction, and assessment practices;

• Professional development programs should maintain a sustained focus over time, providing opportunity for continuous improvement. Professional development should actively involve teachers in observing, analysing, and applying feedback to teaching practices;

• Professional development should concentrate on specific issues of science content and pedagogy that are derived from research and exemplary practice. Programs should connect issues of instruction and student learning of knowledge and skills to the actual context of classrooms;

• Professional development should promote collaboration among teachers in the same school, grade, or subject;
• Professional development should model a well-defined image of effective classroom teaching and learning.

A study by Yoon, Duncan, Lee, and Shapely (2008) explains how professional development impacts teachers’ learning and thus classroom teaching and student learning. This study reveals that teachers’ “professional development affects student achievement through following three steps:

• First, professional development enhances teacher knowledge, skills, and motivation;
• Second, better knowledge, skills, and motivation improve classroom teaching;
• Third, improved teaching raises student achievement. (p.3)

They added that these three links are connected and if one link is weak or missing, better student learning cannot be expected. However, it was pointed out that if teachers’ fail to apply new ideas from professional development to classroom instruction, their students will not benefit from the teacher’s professional development. “In other words, the effect of professional development on student learning is possible through two mediating outcomes: teachers’ learning and instruction in the classroom”. (p.3)

Consequently, in many education systems, effective professional development is considered to develop both content knowledge and pedagogical knowledge. Perera and Stocklmayer (2013) have stated that:

It is possible to advance scientific awareness and understandings amongst teachers in ways that are personally meaningful. Effective science and technology communication practices are critical in this regard. In turn, teachers modelling these practices with their students will facilitate the kind of learning that fosters a continuing engagement with science. (p.192)
Wilson, Shulman and Richard (1987) reported earlier that successful teachers cannot have only a personal understanding of a concept, idea or theory. In order to cultivate understanding in their students, the teachers must themselves understand ways of representing the concepts for the students. They must have knowledge of the ways of transforming content for the purpose of teaching. They must have knowledge of subject matter that includes personal understanding of the content as well as knowledge and skills to communicate that understanding in the minds of students. Strong, Silver and Perini (2001) suggested that the main focus of professional development should be students, and how to improve students’ performance. Therefore, there is a need to link the education of teachers to student learning.

Professional development needs to help teachers continuously improve by better understanding those students’ learning needs. By creating learning experiences to address the needs of students, teachers are able to apply new strategies in the classroom; i.e. refining their present learning into more powerful lessons, reflecting on the impact on student learning, and repeating this cycle with new goals. Supovitz and Turner (2000) stressed that “The implicit logic of focusing on professional development as a means of improving student achievement is that high quality professional development will produce superior teaching in classrooms, which will, in turn, translate into higher levels of student achievement”. (p.965)

There are many factors which make it hard for teachers to participate in professional development activities. According to Wilson and Corbett (2001, p.9), the most important factors are as follows:
<table>
<thead>
<tr>
<th>Time constraints:</th>
<th>Teachers are busy in the school whole day; it is difficult for them to go for part-time and full time development sessions, to participate regularly and for extended period of time.</th>
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<tbody>
<tr>
<td>Financial constraints:</td>
<td>Some professional teachers training programmes in some countries are expensive.</td>
</tr>
<tr>
<td>Distance:</td>
<td>Sometimes teachers need to travel long distances.</td>
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<tr>
<td>Information gap:</td>
<td>Many teachers do not have information about the teacher training programmes.</td>
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<tr>
<td>Lack of face-to-face interaction:</td>
<td>There may be limited opportunities to meet and talk with teachers from other schools</td>
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<tr>
<td>Mismatch of goals:</td>
<td>There is a mismatch between the goals of professional development and individual practitioners professional interests.</td>
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In a study conducted by Farkas, Johnson and Duffett (2003), fifty percent of the teachers stated that their professional development made little difference in improving their teaching practice. According to Sparks (2002):

> More often than not, staff development for teachers is fragmented and incoherent, lacks intellectual rigor, fails to build on existing knowledge and skills, and does little to assist them with the day-to-day challenges of improving student learning. (p.85)

For teachers, learning occurs in many different aspects of practice, including their own classroom while they are teaching, their school communities, and professional development courses, seminars or workshops. It can occur in a staffroom in the school, conversation with a colleague, or after school when counselling a troubled student. Professional development rewards teachers with personal and professional growth, job security, and career advancement in teaching. However, professional development is a
lifelong process. In this process, schools should support the idea that everyone is always engaged in learning, not just students but also teachers. Fullan (1993) suggested that, beyond better pedagogy, the teacher of the future must actively improve the conditions for learning in his or her immediate environment. He said that teachers will never improve learning in the classroom (or whatever the direct learning environment) unless they also help improve conditions that surround the classroom. Fullan and Hargreaves (1991, p.64) developed twelve guidelines for action consistent with this new conception of "interactive professionalism", amongst these were:

- locate, listen to, and articulate your inner voice;
- practice reflection in action, on action, and about action;
- appreciate the total person in working with others;
- redefine your role to extend beyond the classroom;
- commit to continuous improvement and perpetual learning; and
- monitor and strengthen the connection between your development and students' development.

Moreover, professional development is a critical link among new policies, school reform and improved educational practice (Knapp, 2003). According to Hattie (2003):

We have poured more money into the school buildings, school structures, we hear so much about reduced class sizes and new examinations and curricula, we ask parents to manage schools and thus ignore their major responsibility to help co-educate, and we highlight student problems as if students are the problem whereas it is the role of schools to reduce these problems. Interventions at the structural, home, policy, or school level is like searching for your wallet which you lost in the bushes, under the lamppost because that is where there is light. The answer lies elsewhere - It lies in the person who gently closes the classroom door and performs the teaching act- the person who puts into place the end effects of so many policies, who interprets these policies, and who is alone with students during their 15,000 hours of schooling. I therefore suggest that we should focus on the greatest source of variance that can make the difference – the teacher. (pp.2-3).
Within the climate of reform, the earlier concept of reflection in practice has been accorded new recognition. Dewey (1933) had developed the concept of reflective practice and reflection through experiential learning theories. According to him, the experience the individual lives through can be described as a dynamic continuum, and each experience influences the quality of future experiences. Reflection helps the learner to think about what and how they learned and to understand, and later how they can apply that learning in the new situation. John Dewey (1932) said that "we do not actually learn from experience as much as we learn from reflecting on experience" (p.19). Birmingham (2004) states, "the very word reflection is a metaphor that suggests an act of private, personal, and intimate examination of oneself in a mirror" (p.321). This act of private and personal examination of various experiences that take place in the classroom is an act of self-study that is a viable way to promote meaningful, purposeful reflection.

Schon (1983) suggests that we can engage in reflection in one of two ways: either by reflecting on action after the experience, or by reflecting in action during the experience. The teachers "...must encourage and engage in activities that connect the knowing- and reflection-in-action of competent practitioners to the theories and techniques taught as professional knowledge in academic courses" (Schon, 1987, p.312). Later, Boud, Keogh and Walker (1985) explained that reflective practice features the individual and his or her experiences, leading to a new conceptual perspective or understanding. Effective learning will not occur unless the learner reflects. This means the learner must recall a particular moment, think it over, go back through it and then only will the learner gain new insights into different aspects of that
situation. Boud et al., (1985) included the element of learning, as well as involvement of the self, to define reflective practice:

Reflection is an important human activity in which people recapture their experience, think about it, mull it over and evaluate it. It is this working with experience that is important in learning. (p.18)

Kenny (2010) found that reflective process was important for pre-service teachers to make connections between theory and practice. Reid (1993) noted that reflection is not simply recalling previous experiences but it is an active process rather than passive thinking. In her definition, she states that:

Reflection is a process of reviewing an experience of practice in order to describe, analyse, evaluate and so inform learning about practice. (p.305)

Nevertheless, many teachers are not prepared to implement new research into teaching and learning. They are still using a model of teaching and learning that focuses on memorising facts without emphasising deeper understanding of subject knowledge (Cohen 1990; Darling-Hammond & Maclaughlin, 1995). We need a more balanced approach where teachers lay greater emphasis on understanding of subject matter. Tomlison and Jarvis (2006) explained that “teachers, who see strengths in students, teach positively; teaching to student strengths helps students see themselves positively”. (p.16)

Teacher learning is an important and active area for research in education, and research into learning science has not focused particularly on teacher learning (Fishman & Davis, 2006). Many studies on teacher learning underline the importance of experience. These studies, however, rely mainly on teachers’ own past experience, whether it was rich or poor. The National Commission on Teaching and America’s Future (1996) states that:
What teachers know and can do makes the crucial difference in what
teachers can accomplish. New courses, tests, curriculum reforms can be
important starting points, but they are meaningless if teachers cannot
use them productively. Policies can improve schools if the people in
them are armed with knowledge, skills and supports they need. (p.5)

Teachers, therefore, need learning and reflective experiences that engage them to make
their science concepts and pedagogy effective. As stated by James and Pollard (2006),
“A chief goal of teaching and learning should involve acquiring a repertoire of learning
strategies and practices, developing positive learning dispositions, and having the will
and confidence to become agents in their own learning” (p.7). Teachers obtain these
extra ingredients by attending relevant courses, seminars and workshops outside the
school and come back with fresh energy, new ideas, and are able to face challenging
problems.

**In summary**, professional development of teachers is essential for their personal and
professional growth, job security, for their career path to improve themselves, their
schools and their students. Professional development is considered to develop both
content and pedagogical needs of the teacher. Professional development programmes
help teachers to build content and pedagogical knowledge and examine their practice.
They provide opportunities for the teachers to learn science as it should be taught to the
students and help teachers to focus on programmes which are student-centred. Some
studies mentioned the benefits of reflection for teachers to recapture their experience
think about it, evaluate it and how they would use it in their classroom teaching.
Professional development which is held outside the school is more effective, but must
be regularly attended by teachers. One possibility in this regard is to explore the
relationship between professional development and informal learning.
Learning in Informal Settings

In the 1960s, the U.S. National Science Foundation supported seven major elementary and junior high school science curriculum projects and many teacher education workshops. The development of a new paradigm for elementary science teacher education focused, amongst other things, on professional development. The National Science Education Standards (NSES, 1996), in stating that the most important resource for teaching science to students is professional teachers; also commented:

Teachers must be prepared to teach science to students with diverse strengths, needs, experiences and approaches to learning. Teachers must know the content they will teach, understand the nature of learning, and use a range of teaching strategies for science and good science programs require access to the world beyond the classroom". (p.218)

This can be achieved through informal learning environments because these places have a variety of objects on public display that have the potential to complement classroom learning. Connecting museum visits to topics that are presented in the classroom could allow teachers to build deeper understandings of topics and facilitate experiences that reach a wider range of learners (Cox-Peterson, Marsh, Kisiel & Melber, 2003).

A brief mention about formal learning is made here, before moving to describe informal learning contexts. Formal education refers to an institutional ladder that goes from preschool to graduate level studies (Schugurensky, 2000). According to him, formal education has the following features:

- It is highly institutionalized. It includes the period called basic education which varies from country to country;
- It is pro paediatric in nature. At each level, it prepares the learner for the next one;
• Learning is structured into topics, dictated by the requirements of examinations and confined by timetables;
• It is a hierarchical system; and
• At the end of each level and grade, graduates are granted a diploma or certificate that allows them to be accepted in the next grade or level. (p.1)

Formal education is delivered by specialised organisations representing the school system from pre-primary to secondary (Salmi, 1993; 2003; 2012). The relationship between the different kinds of education is shown in Figure 1, which combines several sources (Salmi 1993, 2003).

Salmi (2012) described formal education as education given by specialised organisations representing the school system from pre-school to university. (p.47) Formal learning is institutionally sponsored or highly structured, i.e. learning that happens in courses, classrooms, and schools, resulting in learners receiving grades, degrees, diplomas, and certificates, whereas informal learning is learning that rests primarily in the hands of the learner and happens through observation, trial and error,
asking for help, conversing with others, listening to stories, reflecting on a day's events, or stimulated by general interests (Cross, 2007; Selwyn, 2007). Informal education is education given by different institutes whose first function is not to educate, for example, libraries, youth free-time organisations, and learning centres. Self-education is included in informal education.

Formal science learning in the classroom has been distinguished from informal science learning by various authors in different ways (see for example, Lucas, 1983; Marshall, 1993; Stocklmayer et al., 2010). More recently, Yeo (2014) stated that formal “school science learning tends to be confined within the four walls of the classroom, disjointed from learning that might take place in other contexts such as structured/non-structured enrichment or hobbies” (p.237). Informal learning, on the other hand, is different. For instance, Livingstone (1999, p.51) defined informal learning as any activity involved in the pursuit of understanding, knowledge or skills which occurs outside the curricula of educational institutions, or the courses or workshops offered by educational or social agencies. Other authors have made a distinction between intentional and unintentional sources of informal science learning by means of television, newspaper and intentional aims to teach as in museums and in science centres (Lucas, 1983).

There does not appear to be a single definition of informal learning, nor is there a standard list of domains where it occurs. Generally, the term refers to “science learning that occurs outside the traditional, formal schooling realm” (Dierking et al., 2003, p.108). Wellington (1990) found that informal learning consists of properties such as “voluntary, unstructured, non-assessed, open ended and learner-centered” (p.248). Robert Russell (2004) has added that informal learning is not bounded by time limits.
He wrote that formal learning is a contrast to informal learning; it is structured, graded, time limited and involuntary. In informal learning environments, however, the learners are motivated, which makes their subject interesting and meaningful to them. Semper (1990) has added that the curiosity of the learner adds to the joy of learning potential.

According to Bell, Lewenstein, Shouse and Feder (2009):

There is mounting evidence that structured, non-school science programs can feed or stimulate the science-specific interests of adults and children, may positively influence academic achievement for students, and may expand participants’ sense of future science career options. (p.3)

In a report of the National Research Council of the National Academies, Bell et al., (2009) state that informal learning environments can support science learning. These places are enriched with educationally framed real-world phenomena, these are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through conversations (p.293). Jung and Tonso (2006) found that informal learning environments such as museums and science centres provide a non-threatening environment for the teachers that is more conducive to inquiry-based instruction. This view is shared by other researchers, such as Holliday, Lederman and Lederman (2014), who claim that informal learning environments often create a non-threatening environment for teachers participating in professional development programmes and help them to encourage their confidence in teaching science to their students by providing a safe environment. Stocklmayer et al., (2010, p.16) describe the setting for informal learning places, based on study by Rennie (2007): out-of-school learning environments where: (a) both attendance and involvement are voluntary or free-choice, rather than compulsory or coercive; (b) the curriculum, if any, and whether intended or not, has an underlying structure which is open, offers choices to learners and tends not to be transmissive; (c) the activities in which learners can be involved are non-evaluative and non-competitive, rather than assessed
and graded; and (d) the social interaction is amongst groups likely to be heterogeneous with regard to age, rather than constrained between same-age peers and formalized with the teacher as the main adult. In sum, compared to formal school environments, learning in the informal sector “is learner-led and intrinsically motivated, rather than teacher-led and extrinsically motivated” (p.127).

James and Pollard (2006) recognised the significance of informal learning, such as learning out of school, and mentioned that it should be seen as being at least as significant as formal learning and should be valued and used in formal processes (p.8).

The two however, should be seen as complementary. Recently, Cross (2007) argued that formal and informal settings are both conducive to learning, they co-exist and both have important roles to play. Blending of formal and informal learning experiences provide better results because they both involve building new neural connections in the brain and adapting to new conditions. Hall (2009) also suggests that formal and informal learning should be connected to optimise learning and that learning is most effective when the learner engages in both formal and informal learning activities. However, informal learning is less predictable, it can happen intentionally or inadvertently. Nevertheless, in practice informal learning is often considered more effective than formal learning, because it is personal, it is real, it is a natural way of learning, customised and the learner is motivated, responsible and open to receiving it (see also, De Vries, 2008; Hoffman 2005). Cross (2007) considers formal and informal learning “ranges along a continuum of learning” (p.16) rather than either-or dichotomies. According to Cross, as cited by De Vries 2008:

The distinction between formal and informal learning should not be understood as a strictly separated set of learning activities, but a learning spectrum with formal learning depicted as a traditional classroom oriented, curriculum bound learning and informal learning as a social activity consisting of a mix of actions that support learning on the go, it’s the way people have learned for years. (p.2)
**Experiential learning**

According to Duran, Ballone-Duran, Haney, and Beltyukova, (2009):

The influence of informal science education has long been acknowledged as an effective tool to enhance the more formal methods of classroom teaching and learning. The successful integration of informal science education can serve as a powerful catalyst encouraging students and teachers to have unique, memorable, and motivating learning experiences in settings that extend far beyond classrooms. (p.53)

Duran et al., (2009) argue in addition, that informal science education in informal places promotes student and teacher learning experiences outside the classroom. By strengthening experience from both formal and informal institutions, it can contribute to the creation of a more interested and receptive audience for future and lifelong science learning (Chin, 2004; Bell, et al., 2009).

The U.S. National Science Teachers Association (NSTA, 1998) highlighted the importance of informal learning institutions in a position statement on informal science education. It stated that:

informal science learning experiences offer teachers a powerful means to enhance both professional and personal development in science content knowledge and accessibility to unique resources. (p.17)

Informal science institutions can therefore, be powerful centres of science learning expertise, resources, and experience in their communities for teachers. According to Association of Science-Technology Centres (ASTC, 2007):

Teachers have much to teach us about our communities, about our children, and about being accountable for teaching practices. At the same time, informal science institutions have much to offer teachers, notably (a) strategies and resources for engaging and sustaining student interest in science and (b) science-rich professional communities that can nourish and sustain teachers themselves. Working together, informal and formal educators can expand their repertoires of practice so that science learning, across multiple settings, becomes more engaging and coherent for more children”. (p.2)
In 2007, the U.S. National Science Board (2007) recommended the coordination of formal and informal education efforts to support teacher development through direct activities with students and professional development opportunities for the teachers. The action plan states that museums and similar organisations should provide invaluable supplements to support teachers’ learning (NSB, 2007).

New learning experiences of teachers can be related to their personal experiences. Kolb (1984) states, for instance, that “learning is the process whereby knowledge is created through the transformation of experience” (p.38). Experiential learning supports the learner-centered approach and places emphasis on direct engagement by the learner. According to Kolb’s learning cycle, learning experientially requires the learner to have an experience and then reflect, analyse and test the idea to develop knowledge and to create another experience. A person is more likely to learn if the experience has significance for that person. The degree of learning is also based on the learner’s own background and experience (Rennie, 1998). Learning is based on making links and connections with previous experience. For example, Falk and Dierking (1992) reported that “reinforcement, consolidation and reshaping of knowledge are critical aspects of the learning process” (p.120).

Experience-based learning has been characterised by Boud, Cohen and Walker (1993) as follows:

- Experience is the foundation of, and the stimulus for learning;
- Learners actively construct their own experiences;
- Learning is a holistic process;
- Learning is socially and culturally constructed;
- Learning is influenced by the socio-emotional context in which occurs (pp.814).

Much earlier, John Dewey (1938) had considered experience to be a great source of learning through which meaning can be found and then built upon. The rationale for experience in teacher learning is based on his work which spearheaded the progressive movement in the 1930s and emphasised learner-centred instruction. He was a strong supporter of experiential learning (Huling, 1998). Dewey (1938) claimed that all genuine education occurs as a result of experience, and modern educators continue to emphasise the value of experiential learning as an essential element in teacher education. Dewey viewed a teacher as a learner, and noted that learners need experiences for constructing their own learning. According to Dewey problems to be studied must be related to students’ experiences and within their intellectual capability. Therefore, the students are to be active learners in their search for answers. He believed that every experience should prepare a person for later experiences of a deeper, more expensive quality:

  Only by extracting the full meaning of each present experience are we prepared for doing the same thing in the future (p.49).

According to Meier (1995), "there are, in the end, only two main ways human beings learn: by observing others (directly or vicariously) and by trying things out for themselves" (p.181). The experience of learning is however, not easily observed nor is there any method to observe whether there is any gain in knowledge. The only way to gauge outcomes is through the action or reaction of the learner (Rennie & Johnston, 2004). Schutz (1967) has mentioned that each of us is embedded in a continuous flow of experience throughout our lives.
Experience-based learning, “is an individual process in which each learner may make different meanings from the same new experience as they each carry a different set of prior understandings” (Griffin, 1999, p.18). Griffin reported that people respond differently to an experience depending on the environment in which they encounter that experience. Field trips constitute an important environment in which informal learning may take place, complemented by formal science learning (Kisiel, 2006; Tal & Morag, 2009).

Field Trips: Informal learning outside the school

According to Krepel and Duvall (1981), a field trip is:

A trip arranged by the school and undertaken for educational purposes, in which the students go to places where the materials of instruction may be observed and studied directly in their functional setting: for example, a trip to a factory, a city waterworks, a library, a museum etc. (p.7)

As Rudman (1994) described:

Field trips can create relevancy to science classroom learning when connected to the outside world, encouraging science interest and possibly increasing students’ aspirations for science-related careers. (p.139)

Thus the visits to the Science Enrichment Programme at the Science Centre Singapore fall into the ‘field trip’ classification and much of the literature on this topic is relevant to the teachers who attend these programmes.

Researchers note that teachers provide field trips to students for a variety of reasons including motivation, exposure, an interactive setting, as a reward, and to support what they are teaching in the class. Studies have pointed to the long-term impact of field trips, especially by way of memories of the specific experience (see for example,
A study conducted by Falk and Dierking (1997) found that nearly all of the individuals they interviewed could remember at least one thing they had learned during their primary school field trip. Most of the individuals could relate three or more things many years after the field trip ended, thus showing the significant impact a field trip can have on students. In another study, Nazier (1993) interviewed 300 full-time science and engineering professors to find out what factors motivated them to choose science as a career. He found that one of the leading factors was a field trip experience. Athman and Monroe (2008) noted that field trips enhance students’ cognitive, affective, social and behavioural change and make learning useful for students to grasp, while increasing motivation for learning (see also Kern & Carpenter, 1984).

Field trips and outdoor teaching have always been important and teachers mostly take students on field trips for informal learning experiences (Tal & Morag, 2009). Field trips convey more positive attitudes toward science and environmental concepts (Athman & Monroe 2008; Bitgood, 1989). Field trips are usually arranged by schools, mostly with an educational purpose, and take place in an interactive environment or setting (see Dillon, Morris, O’Donnell, Reid, Rickinson & Scott, 2005; Hofstein & Rosenfeld 1996; Krepel & Durral 1981; Rickinson, Dillon Teamey, Morris, Choi, Sanders & Benefield, 2004). Teachers usually conduct field trips to nature parks, zoos, museums, science centres, and other education-related environments (Falk, 2001; Tal & Morag, 2007). All these environments have a meaningful impact on both students’ and teachers’ cognitive, affective, social and behavioural aspects and contribute to the success of their learning (Dillon et al., 2005). Teachers take their students on field trips because of the many advantages, and because this type of learning is not possible in
schools. It was reported by Cox-Petersen, Marsh and Kisiel (2003) that the teachers’ main purpose of taking students on a field trip is to have experiences that they cannot provide within the class. Through field trips, learners have opportunities for observation and examination, and the opportunity to discuss their ideas in a socio-cultural environment (Rogoff 1990; Falk & Dierking, 2000). Research has suggested that the advanced preparation of students and establishing a link between the field trip and the curriculum are the most influential factors in a field trip being educationally-effective (Davidson, Passmore & Anderson, 2010; Orion & Hofstein, 1994; Bitgood, 1989).

Orion (1993) reported that on field trips, teachers and students acquire learning experiences with real materials. Morrell (2003) emphasized that the success of a field trip is based on three tenets: pre-visit preparation and instructions given by the teachers; active involvement by students during the trip; and teachers following up on the field experience. The last is very important.

Orion and Hofstein (1994), and Michie (1998) have said, however, that field trips are mostly neglected by teachers, curriculum developers and researchers. Problems with field trips have been recorded for many decades. Over thirty years ago, Mason (1980), and Fido and Gayford (1982) reported that teachers avoid field trips because they are unfamiliar with the techniques and organisation of field trips. Moreover, teacher training seldom includes programmes or workshops that address learning that occurs outside of the classroom (Ferry 1995; Tal, 2004). The problem still exists. Tal and Morag (2009) stated that:

Pre-service and in-service teachers get many opportunities to learn in many outdoor environments, they usually participate in such field trips only as passive learners and are not required to employ pedagogical considerations and to put themselves in the place of a teacher (p.246).
Field trips and teachers: Preparation and follow-up

Research indicates that teachers have to face many difficulties such as administrative, and other logistical planning when preparing students for field trips (see, for example, Dillon, Rickinson, Teamey, Morris, Young, Choi & Sanders (2006); Kisiel 2003; Olson, Cox-Petersen & McComas, 2001; Tal & Steiner, 2006). Some teachers face difficulties such as transportation, admission costs, skills, time constraints, preparation, curriculum inflexibility, lack of support from school administrators, poor student attitudes and behaviours, and inadequacy of resources (Falk & Balling, 1979; Orion, 1993; Price & Hein, 1991). Therefore, Athman and Monroe (2008) stated that field trips cannot be successful unless they are carefully planned. They mention that too often, field trips are isolated from the school curriculum. Ferry (1995) has shown that there is less transfer of learning and meaning when a field trip is not related to classroom teaching. The field trips should be integrated into the broader instructional programme and used only when they are most effective. For example, recent findings conducted for 158 teachers (87 from primary and 71 from secondary) by Morentin and Guisasola (2015) revealed that most teachers who visited “Eureka Science Museum” in San Sebastián with their classes scarcely prepared for the visit, i.e. they did not have a clear idea of how to use the museum as an informal resource for learning about science. Furthermore, they did not use their professional pedagogical knowledge when organising the visit. Also, teachers rarely performed pre-visit activities to connect the visit with the class curriculum or do post-visit activities to draw conclusions (p.208).

Kisiel (2006) reported that the other important factor which teachers usually ignore in conducting field trips, and one they find difficult, is to follow-up. According to him, the reason is the overcrowded curriculum back at the schools, which prevents discussion or
reinforcement of the field trips. However, research on field trips suggests that the follow up is a critical part of the experience, as it helps students to reflect and recall some of the ideas developed during the field trips. Kisiel (2006) added that, if the field trip has been effectively incorporated into the curriculum, the follow up simply is the next lesson.

Table 1: Summary of the different challenges encountered by teachers during field trips.

<table>
<thead>
<tr>
<th>Field trips</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field trip goals poorly defined</td>
<td>Griffin &amp; Symington (1997)</td>
</tr>
</tbody>
</table>
| Neglected by teachers, curriculum developers and researchers | Michie (1998)  
Orion & Hofstein (1994) |
| Unfamiliar with techniques              | Fido & Gayford (1982)  
Mason (1980)  
Behrendt & Franklin (2014) |
| Lack of curriculum materials            | Hickman (1976)                                                        |
| Uncertainty of teacher role             | Kisiel (2005)  
Griffin and Symington (1997)  
Tal, Bamberger & Morag (2005) |
| Isolated from school curriculum         | Hickman (1976)  
Griffin & Symington (1997)  
Ramey-Gassert, & Walberg (1994)  
Tuckey (1992) |
| Not integrated into classroom learning  | Jensen (1994)  
Kubota & Olstad (1991) |
| Purpose of the visit not defined        | Tal et al., (2005)                                                    |
| Learning opportunities fails to inspire students | Jensen (1994) |
| Difficulties in planning pedagogical and logistics work | Dillon, et al.,(2006)  
Kisiel (2003)  
Olson, et al, (2001)  
Tal & Steiner (2006)  
Tal & Morag (2009) |
| Transport cost is expensive             | Mehta (2008)  
Price & Hein (1991) |
| Teacher needs to consider safety issues | Behrendt & Franklin (2014)  
Dillon et al., (2006) |
Some studies on field trips by school groups have revealed that teachers often have poorly defined goals for field trip visits, which sometimes affects the learning during these visits (Tuckey, 1992). A study conducted by Griffin and Symington (1997) has shown that only about fifty percent of teachers whom they interviewed during their study were able to describe the purpose of their field trips. They also added that less than half of the teachers interviewed during the field trip considered the field trips were linked to the classroom curriculum. Table 1 presents a summary of the different challenges encountered by teachers during field trips. The issues identified have been derived from a large body of literature.

Griffin (1998) did a study involving field trips to museums in Sydney Australia, and she found that teachers stated different purposes for going on field trips. In her study, she found that learning during the field trips is related to the school curriculum. On the other hand, some teachers explained that they were uncomfortable with their capacity to manage their students in an unfamiliar environment. She felt that teachers are perhaps ignorant of, or unable to understand many of the principles of learning in informal environments, such as learning through play and direct involvement with phenomena. Griffin (1998, p.97) summarised some following suggestions for the field trips for teachers so that teachers can derive greater benefits from their visits.

- teachers and students have a clear, shared purpose;
- the visit is linked to class work;
- students are given preparation at school for the excursion;
- worksheets are used with care to facilitate choice in learning;
- students are given choice in their learning activities;
- students’ curiosity is fostered;
• students are encouraged to share their learning with peers and adults;
• students are encouraged to use the full range of learning opportunities provided by the venue;
• teachers participate in the learning process and model appropriate learning behaviours.

In addition, Kisiel (2005, p.941) proposed the following eight distinct motivations for field trips:

1. To connect with a classroom curriculum: Teachers see the field trip as an opportunity to reinforce or expand upon the classroom curriculum;
2. To expose students to new experiences: Teachers see the field trip as an opportunity to provide rich and novel experiences to students who may not have the opportunity otherwise;
3. To provide general learning experience: Teachers see the field trip as an opportunity to provide a memorable learning experience;
4. To foster students’ interest and motivation: Teachers see the field trip as an event that fosters students’ interest, curiosity and motivation;
5. To provide a change of setting or routine: Teachers see the field trip as an opportunity to get out of the classroom and change routine;
6. To promote lifelong learning: Teachers see the field trip as an opportunity to show students that learning can happen beyond school, among friends and family;
7. To provide student enjoyment and reward: Teachers recognize that the field trips should be positive and enjoyable experiences for the students;
8. To satisfy school expectations: Teachers are expected to conduct a field trip, per school policy or peer pressure.

**Teacher’ learning on field trips**

Considering, teachers’ own learning experience during field trips, Dillon et al., (2005a) explained that field trips help teachers in their personal development and in their teaching. Such field trips also improve their personal relationship with the students and lead to benefits in the learning derived from the curriculum. They stressed that these out-of-school experiences give opportunities to teachers to have direct experiences with concrete materials, through a gradual shift from simple to complex concepts and also hands-on experiences. However, they stated that visits gave opportunity to the teachers:

“to observe outdoor educators and to learn from their expertise and different styles of teaching …enabled them to learn new subject knowledge and to acquire new skills and ideas that they could apply in their classroom. Teachers recognised the opportunities that outdoor education provided to interact with their students in relaxed, informal environments. They reported benefiting from the break from the normal teacher-pupil relationship”. (p.2)

The emphasis on social interactions was also reported by Gottfried and Rosenfeld (1980a). Aggarwal (2003, cited in Shakil, Faizi & Hafeez, 2011) commented:

Educational field trips are helpful for the teachers to clarify, establish, co-relate and coordinate accurate concepts, interpretations and appreciations and enable [him] to make learning more concrete, effective, interesting, inspirational, meaningful and vivid. Thus we can say that educational field trips are helpful in completing the triangular process of learning that is motivation, clarification and stimulation. (p.3)

Quantitative studies of the approach of teachers towards field trips were undertaken by Falk and Balling (1979) and by Fido and Gayford (1982). Importantly, they too found
that teachers derived benefits from the field trips which incorporated hands-on real world experiences.

The kind of learning teachers experience on field trips may be described as *incidental learning*. According to Marsick and Watkins (1990):

> Formal learning is typically institutionally sponsored, classroom based, and highly structured. Informal learning, a category that includes incidental learning, may occur in institutions, but it is not typically classroom-based or highly structured, and control of learning rests primarily in the hands of the learner. Incidental learning is defined as a by-product of some other activity, such as task accomplishment, interpersonal interaction, sensing the organisational culture, trial and error experimentation, or even formal learning. Informal learning can be deliberately encouraged by an organisation or it can take place despite an environment not being highly conductive to learning. Incidental learning on the other hand, almost always takes place although people are not always conscious of it. (p.12)

Learning in an informal environment may be incidental (Marsick & Watkins, 1990), unplanned (Straka, 2004), and may even take place beyond the learner’s awareness (Eraut, 2004). In the literature regarding informal learning in the workplace (Marsick & Watkins, 1990; Eraut, 2004), it is argued that this learning partly remains implicit and it is not available to the learner’s conscious awareness.

**In summary**, Field trips have been identified as one of the most important teaching and learning experiences for both teachers and students. Field trips create relevance to science classroom learning and make connections to the outside world not possible in the classroom. Teachers organise field trips for many reasons including new teaching materials, interactive settings, first-hand experiences, as an enrichment, and to support what they are teaching in the class. All these experiences during field trips have a meaningful impact on students and teachers. These impacts may be cognitive, affective,
or social. Critically, there are suggestions in the literature that teachers also benefit. Several authors have noted that during field trips teachers improve their relationship with students, have personal learning experiences, gain confidence, expand on their curriculum and bring their learning experiences back to their classrooms. This learning has been identified as incidental learning.

However, it is not clear from the literature what teachers do during the field trips which are organised for the students, what learning takes place and how teachers translate the experience back in the classroom.

**Learning in Science Museums and Science Centres**

For the purpose of this study *science museums* and *science centres* will be regarded as one entity. Science centres are the most important informal learning settings for science learning (Senturk & Ozdemir, 2014, p.2). Museums are important and well-respected educational, social and cultural resources for visitors of all ages and wonderful places for communicating science (Durant, 2014). Recently, Durant (2014) recommended that science centres should play an important role in terms of enthusing young people and adults about science: “it is not the buildings that make a science centre-it is the content of those buildings, the activities and the enthusiastic people who operate and deliver them that makes the science centre” (p.84).

Science centres provide links with schools to help with professional development of teachers and outreach programmes. In particular, they serve as learning environments for students and teachers who visit and participate in the different type of activities organised therein. Durant stated that there are about 2,400 different science centres or
related organisations worldwide which attract about 300 million visitors annually. These are mainly children and families, teachers and school groups and young adults (p.82). Some science centres even run schools and deliver curriculum support for the region, and a few offer teacher training as an alternative route into the teaching profession. Primarily, science centres are about motivation, but they support education and informal learning (Durant, 2014, p.83).

Science centres are unique institutions which can provide resources for lifelong learning as well as complementing studies in school programmes. According to Jarvis and Pell (2005), these institutions are important and can address aspects of science education that might be missing in more formal, class-based science learning, to provide an awareness of the relevance of science to society (p.53). Science centres and museums are considered to have a major role in the informal learning of science (Rennie & Williams, 2002; Shamos, 1995). Science centre settings afford many science teaching and learning experiences that are not available in classrooms, zoos, shopping malls or botanical gardens. As far back as 1992, the most popular destination for field trips and most studied informal learning settings was science museums and science centres. Science centres offer opportunities for visitors to interact with materials, objects and ideas which may not otherwise be readily available to learners (Russell, 1994). Science centres and museums are seen as important resources in supporting the teaching of science for schools (DeWitt & Hohenstein, 2010).

Gilbert (1995) stated that the diverse range of resources made available by museums, relevant to school topics in the curriculum, makes organised visits very attractive to schools. This is still true twenty years later. For example, Falk and Dierking (1997), and
Mackety (2003) state that primary school students and their teachers are the main audience for museums, which invest considerable resources in promoting and supporting elementary school field trips. Consequently, the quality of classroom preparation, activities within a science centre, and follow-up activities are all important aspects of visits (Anderson, Lucas, Ginns, & Dierking, 2000).

Over the past few years, science centres have been developing their understanding of how to approach audiences; especially schools, to link their interests and attitudes according to their needs. Moreover, current research provides evidence that school trips to such places can result in both cognitive and affective gains for students (Anderson, Kisiel & Storksdieck, 2006). This view is supported by Gilbert and Stocklmayer (2001) who note that interaction with exhibits could bring out memories of previous experiences, which constitutes a link, enabling to the construction of the present experience to the past experience. Hence, the learning for teachers and students becomes very successful if they can combine their past and present experiences.

Museums and science centres, nowadays, appear to be a cross between a computer technology exhibition and a playground. Opportunities for informal learning in science centres are more numerous and diverse than ever before (Owens, Lecrubier & Breithaupt, 2002). They reflect many of the efforts across the spectrum of informal learning that are being used to make science and technology interesting for younger generations. Apart from being an attraction for children, science centres and museums also play another important role in the continuing education of students. They provide the necessary knowledge, experience and materials for making modern science appealing (Owens et al., 2002). School groups have become, therefore, major visitors
and audiences for science centres because the centres are able to provide opportunities for students to learn science and technology in a stimulating environment (Rennie & McClafferty, 1995).

Museum learning has many potential advantages, including improving motivation and positive attitudes about science. It was noted quite early that such sites provide opportunities to engage visitors in active participation, thus addressing concerns that elementary classrooms diminish curiosity with an emphasis on rote learning (Ramey-Gassert & Walberg, & Walberg, 1994, p.345).

Teachers give a number of reasons for taking their students to science centres. Researchers have recommended that teachers engage their students in activities that science centres offer and invite social interaction and exploration. Gottfried (1980) reported that the reasons for teachers’ visits to the Bio lab at the Lawrence Hall of science included: a desire for a change of pace, science enrichment, a social experience for the students, and to increase their exposure to science. Rennie and Elliott (1991) found that teachers took their classes to a science centre in Western Australia for similar reasons.

A survey was conducted in 2002 among elementary-level teachers throughout the Calhoun County, Michigan to identify individual factors that are most likely to influence teachers’ decisions to visit the Kingman Museum with their students (Mackety, 2003). The survey found that:

Teachers prefer programmes from science museums that include ‘hands-on activities, provide unique educational experiences, use a variety of learning styles, exercise students critical thinking skills, help students to apply what they are learning in their daily lives, allow students to be in an
Science centres are indeed educational institutions, but they are not schools. Learning at the museum involves multiple sources of experience and information, which collectively contribute to individuals’ knowledge construction. Falk and Dierking (2000, p.12) developed a “contextual model of learning” to describe learning in museums. Their model, as depicted in Figure 2, includes three interlinked contexts: personal, socio-cultural and physical. The contextual model of learning consists of eight factors within the three contexts, which can influence a learner in the museum. Falk and Dierking suggested that each of these factors should be considered when trying to understand a learner’s experience. Their contention is that if any of the eight factors are neglected, learning in the museum will become difficult.

Figure 2: The Contextual Model of Learning (Source: Falk & Dierking, 2000, p.12).

According to Falk and Dierking (2000) the personal context includes:

- Motivation and expectation: People visit museums for different reasons and what they want to do or expect to see will certainly affect their
overall experience. When their expectations are fulfilled, learning is facilitated. When teachers bring students for enrichment programmes, their learning is affected by their motivation and hence influences their overall experience.

- Prior knowledge, interest and beliefs: visitors’ (whether teachers or students) interests and existing knowledge will influence their choice of exhibits and programmes for participation.
- Choice and control: Learning is optimized when learner is in control and can choose what is intrinsically important and interesting.

And the social context includes:

- Social interaction is an important factor of learning in museums. Because visits to informal science settings occur often in groups, there is room for social interaction among visitors, families, teachers and students. Such interactions and collaborations influence learning.
- Facilitated mediation by others: museum staff and other visitors can impact individual learning.

Last, the physical context includes:

- Advance organisers and orientation: Learning is more likely when visitors are familiar with their surroundings and their expected behaviour.
- Design: Exhibit designs can help or hinder an individual’s interest and understanding.
- Reinforcing events and experiences outside the museum: Events and situations that occur beyond the museums itself can ultimately influence
what is learned from a museum experience. Learning at the museum involves multiple sources of experience and information, which collectively contribute to the individual’s knowledge construction.

Science centres are only alive and lively when visitors, teachers and students are present and interact with exhibits and with each other. When visitors attend science centres, they expect to do things, to participate in activities during their visit. Visitors are not expected to be passive, but to be actively engaged in some manner with everything that concerns them. This is the focus of museum education. A learning experience needs engagement, some mental, physical, or social activity on the part of the learner. Meaning is made from experience according to Rennie and Johnston (2004), and was further described by Gilbert and Stocklmayer (2001) with reference to the PAST model mentioned previously.

The presence of a teacher is important for the success of the visit to the science museums. “The teacher acts as a bridge between the science learned in the school and the museum experience. Science teachers asses the activities more thoroughly and address both content and pedagogical aspects in their feedback” (Tal & Steiner, 2006, p.42). However, there is limited evidence to show how teachers benefit from these experiences. Recently Kisiel (2013) stated that “informal science education institutions, such as museums, aquariums, and nature centres offer more to teachers than just field trip destinations – they have the potential to provide ideas for pedagogy, as well as support deeper development of teachers’ science knowledge” (p.67). Although there is extensive literature related to teacher/museum interactions within the context of the
school field trips, there is limited research that examines other ways that such institutions might support classroom teachers in their learning.

The National Science Teacher Association (1998) highlighted the importance of these informal science institutions in a position statement on informal science education where they stated that “informal science learning experiences offer teachers a powerful means to enhance both professional and personal development in science and content knowledge and accessibility of unique resources” (p.17).

Although the research efforts to support these claims are limited, there are several studies which suggest that the museum environment positively affects teachers’ content knowledge and pedagogical skills (Melber & Cox-Peterson, 2005). Melber and Cox-Peterson, (2005) stated that teachers found a significant difference between museum workshops as opposed to other workshops they attended. Teachers who attended museum workshops said that the ‘hands-on activities and interaction with museum artefacts and specimens’ were the most valuable components of the workshops” (p.111). Through six-month follow-up interviews, these teachers reported that they were applying content and instructional strategies gained from their workshop into their science lessons. These types of programs empower teachers to make better decisions about science instruction by increasing their understanding of community resources available, science content, scientific processes, and pedagogical models. However, this study did not address teachers’ self-reports of gains in content knowledge and pedagogical knowledge when they accompany their students to these learning environments.
In another study conducted by Jung and Tonso (2006), the authors mentioned that “out-of-school institutions benefit pre-service teachers by providing them with positive science teaching experiences, exposure to and practice with hands-on, inquiry-based science lessons and other teaching strategies, in a non-threatening environment, that build confidence in teaching science” (p.20). Teachers actually need to “see” science at work to internalize and understand science concepts at the student level.

Holliday et al., (2014) argued that teachers always have a purpose for visiting science museums. For example, when teachers explore science museums freely they “often purely reacted to the display itself or the novelty of it” (p.936). They found, however, that when professional development staff from museums made explicit connections between exhibits, content, and activities, teachers were more likely to be involved in those activities. Teachers always need to have a direction or connection to the desired content or exhibit. In addition, Holliday et al., (2014) suggested that when designing future informal professional development programmes for teachers, explicit connections to science content and assessments linked to the instructional objectives of the course should be carefully considered.

A recent study by Faria et al., (2012) showed that the development of a science teacher course by a science centre proved to help teachers to capitalise on the opportunities these non-formal institutions offered to enrich and reinforce school science learning. The reasons teachers gave for attending the course were mainly related to their professional needs, namely pedagogical (89%) and scientific (76%) training. Another reason was the fact that the course affords professional credits, which are important for their professional progression (89%).
In another study, Faria and Chagas (2012) observed 52 students and 23 teachers at a science centre in two science exhibitions, a permanent and a temporary one, to observe students’ and teachers’ interactions with the exhibits and explore the behaviour of students and teachers during a school-visit. The results obtained from the study suggested that “to optimise students’ attitudinal and cognitive gains, teachers should assume an active role during the visit, calling students’ attention to a given phenomenon asking them to explain the phenomena under observation, providing support and “scaffolding” between students’ existing concepts and the exhibits”(pp.592-593). Jarvis and Pell (2005) concluded that “teacher training institutions and science museums need to consider how to enthuse teachers’ personal interest in science museum exhibits, because it is clear that, although it is essential to provide pedagogical advice and support, teachers also need to be inspired and enthused themselves.

For this to happen, teachers need to take an active role in facilitating appropriate learning strategies which allow students to benefit from the full potential of museum resources (Griffin, 1998, p.659). However, Tal and Steiner (2006) stated that elementary school teachers rely completely on museum staff for planning their visit to museum, and they rarely prepare their students in advance or took an active part during the class visit. In their study they found that the teachers’ main role was to assist museum guides by maintaining order, watching the students and provided technical help. About 15% were passive and did not prove any assistance during the visit. Only 21.5% teachers were concerned about active participation, concerned about asking questions, referring to class curriculum, and explaining things to their students (p.40). Contini (2005) claimed that teachers ask too many questions and sometimes gave wrong examples trying to help guides to explain things. However, the most common type of communication
between the museum staff and elementary school teacher was administrative (Tal, 2004; Contini, 2005; Tran, 2006).

**In summary**, Science centres and museums afford many science teaching and learning experiences that are not available in classrooms, zoos, shopping malls or botanical gardens. In particular, they provide learning opportunities for students and teachers who visit and participate in the different types of activities organised by them. They offer opportunities that are not available in the schools. They provide the necessary knowledge materials and experiences for making science appealing and engaging and provide interactive ways to encourage inquiry by hands-on investigations.

School groups have become the major visitors and audience for science centres because they are able to provide exciting exhibits, real learning experiences, and themes which enable opportunities for students to learn science and technology in a stimulating environment. Learning in museums involves multiple sources of experience and information, which collectively contribute to individual knowledge construction. Learners’ personal background knowledge and the social and physical environments must be considered in science centre visits in planning and implementing the visits and follow up activities. Some studies mention that benefits to the teachers include supplementing classroom teaching and stimulating interest in the learning. Although many formal and informal science intuitions include education as a part of teachers’ mission statements, the potential role that informal science institutions play in teachers’ learning has yet to be fully realised. This is especially the case when experiences are designed to complement the school curriculum and to provide social experiences for the students modelled on inquiry based learning. The Science Enrichment Programmes at
the Science Centre Singapore are an example of such an experience, since they are complementary to the curriculum and are grounded in inquiry based learning. This style of learning is, however, relatively new to Singapore.

**Learning by inquiry**

*Constructivism*

Learning is not the result of teaching; rather it is the result of what students do with the new information they are presented with. Students are active learners who construct their own knowledge as long as they are paying attention and are motivated. Constructivism is a theory of learning that focuses on the learner and the meaning they make based on their prior experience, knowledge and interests. Fensham, Gunstone and White (1994) noted that the underlying principle of constructivism is that:

People construct their own meaning for experience and for anything told to them. The constructed meaning depends on the person’s existing knowledge, and since it is inevitable that people have had experiences and heard or read different things, all have different (though often similar) meaning for any concept (p.5).

Fosnot (2005) suggested that constructivism was not a theory about how to teach, but a different way to think about how learning takes place through the relationship between teachers and students:

A constructive view of learning suggests an approach to teaching that gives learner the opportunity for concrete, contextually meaningful experience through which they can search for patterns, raise questions; and model interpret, and defend their strategies and ideas (Fosnot, 2005, p.ix).

Chetty (2008) pointed out that knowledge acquired in schools is insufficient; learners must be confronted with many diverse problem-solving opportunities that provide necessary experiences. He added that the constructive learning process interacts in
science centres with all components creating an environment that promotes science achievement.

To provide teachers with a structured path towards constructivist pedagogies, a range of teaching models have been proposed. One of the more frequently used inquiry based strategies in Singapore classrooms is based on the 5E model developed by the Biological Sciences Curriculum Study (BSCS). The instructional model known as the 5E model includes five stages in the teaching and learning process, namely, Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, Taylor, Gardner, Van Scotter, Powell et al., 2006). Tan and Tan (2014, p.73) stated that this model is widely used in science classrooms in the United States and also in Singapore. It provides a framework to enable teachers to plan lessons that have inquiry components infused in them. Each phase has a specific function and contributes to the teacher’s coherent instruction and the students’ formulating a better understanding of scientific and technological knowledge, attitudes, and skills. A detailed instructional model is Bybee’s (2006) version of the 5Es, as follows:

The model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage:</td>
<td>Elicit thoughts or actions by the student that relate directly to the lesson’s objective;</td>
</tr>
<tr>
<td>Explore:</td>
<td>Experiences where students’ current understandings are challenged by activities, discussions and currently held concepts to explain experiences;</td>
</tr>
</tbody>
</table>
Explain: Presentations of scientific concepts that change students’ explanations to align with scientific explanations;

Elaborate: Activities that require the application and use of scientific concepts and vocabulary in new situations;

Evaluate: Culminating activity that provides the student and teacher with an opportunity to assess scientific understanding and intellectual abilities.

The challenges for teachers

The conception of inquiry learning fits well into the ideas of a modern society where individuals actively and creatively construct knowledge. More specifically, NRC (1996) defined scientific inquiry as:

...a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse and interpret data; proposing answers, explanations, and predictions; and communicating results (p.23).

This also requires teachers to be the leaders of inquiry by creating a learning environment that encourages and challenges students to develop their sense of inquiry (P.558). Many teachers are not well prepared for inquiry-based teaching (Weiss et al., 2001). Harris and Rooks (2010) indicated that one of the considerable challenges for teachers is to learn new ways of managing the classroom to position students for learning through inquiry and spend more time in involving students in active participation of scientific practices, such as designing and carrying out investigations, to deepen their learning of science content and broaden their understanding of the nature of science.
In inquiry-based teaching and learning, the main focus is on the different roles that students and teachers adopt compared to those adopted in traditional settings. In Singapore, Tan and Tan (2014) and Zhai and Tan (2015) stated the key difference is that in traditional classrooms, teachers play an active role, the teacher acts as the sole source and arbiter of knowledge and in comparison students play a passive role as recipients of knowledge through recording and memorizing the teacher’s lectures. In contrast, inquiry-based classrooms aim to develop students as active learners who take ownership of their learning and provide opportunities for the teachers to take the role of observer or participant in discussions. The teacher engages students in processing information, designing investigations, interpreting findings, and sharing authority in seeking answers. The teacher’s role at the same time is to understand what their students learnt or have not learnt (Tan and Tan, 2014, p.71). They further stressed that:

Teaching science by inquiry can be challenging for the teachers because teachers must know where their students are located in the learning journey. This requires teachers to actively and continuously elicit information about their students’ learning, what they already know and can do and also what they have yet to know and then adapt and change their teaching plans to cater to their students’ needs (p.71).

Crawford (2000) stated that a teacher's work in an inquiry-based classroom requires taking on a myriad of roles that demand a high level of expertise, However, the teacher in this environment is “like a student herself /himself, always curious and wanting to learn (p.932). Crawford (2000) studied and worked with biology teachers and suggested and found that in inquiry-based classroom the roles of the teacher changed with the change in their tasks. Some of the roles in the classroom are:

- Motivator: involves the teacher encouraging students to take responsibility for their own learning;
- Diagnostician: involves the teacher giving students opportunity to express ideas in order to discern their understandings;
- Guide: involves the teacher directing students and helping them develop strategies;
- Innovator: involves the teacher designing instruction by using new ideas;
- Experimenter: involves the teacher trying out new ways to teach and assess students;
- Researcher: Involves the teacher trying out new ways to teach and assess;
- Collaborator: involves the teacher and students exchanging ideas, and allowing students to take on the role of teacher.
- Learner: involves the teacher opening oneself to learning new concepts (pp.931-932).

One of the important skills teachers need to develop in their inquiry-based classroom is the ability to monitor continuously the current understanding of students so that instructions and activities can be modified and enhanced based on learners’ understanding and engagement (Ruiz-Primo, 2011). Effective inquiry instruction requires that teachers create a series of comprehensible learning experiences that help students to build understanding of scientific ideas over time (NRC 2000). However, research has also shown that enacting inquiry-based instruction is demanding for teachers. Teachers need to learn to engage students in discussion so that they can debate with each other and with their teacher (Harris & Rooks 2010). Often at times, teachers new to teaching science as inquiry will enact inquiry materials in ways that mirror their own long-standing practices (p.233). These are few research studies that actually examine teachers’ instructional practices in inquiry classrooms”. (McNeill & Krajcik 2008, p.54)

Moving to Inquiry-Based Teaching in Singapore

The year 1965 marked the most important turning point in the history of Singapore as a complete political independent country. The new political, economic and
social conditions required national policies to be re-assessed. With the export-oriented industrialization in the late 1960s, the school system experienced a shift in emphasis from academic to technical education. To support the move towards greater excellence in the school system, teacher education was also upgraded in July 1991 with the formation of the National Institute of Education (NIE), and the establishment of the Teachers’ Network in 1998 (MOE, 1998). The purpose of the Teachers’ Network was to develop students into active learners by using critical thinking skills. The aim of this new vision was to create life-long learners by making schools a learning environment for everyone from the teacher to the policymakers. A new primary science syllabus with science as inquiry as its foundation and guiding philosophy was implemented in Singapore from 2008.

More recently, Tan and Tan (2014) indicated that Singapore is mirroring international trends in science education and science educators and policymakers in Singapore are examining ways to infuse an inquiry approach to develop skills and knowledge deemed necessary in the twenty-first century to improve and support students’ learning of science (p.72). The Singapore Ministry of Education (MOE) also accepts that teachers play a critical role in preparing students for the future and in implementing its curriculum for the 21st century.

However, recent studies have revealed that some primary school teachers in Singapore have difficulties in implementing science as inquiry when teaching science their classrooms. For example, a study by Kim, Tan, and Talaue (2013) found that the nature of assessment practices in Singapore largely takes the form of paper-and-pencil format and focuses on canonical content knowledge, which likely steers teachers’ perceptions
of inquiry towards a teacher-guided approach. Similar findings were reported in Poon, Lee, Tan, and Lim (2012) for examining the actual science inquiry practices for four elementary school teachers in Singapore primary school classrooms. It was observed that teachers place importance on (a) preparing students for investigations, both cognitively and procedurally; (b) iterating pedagogical components where helping students understand and construct concepts did not follow a planned linear path but involved continuous monitoring for learning; and (c) synthesizing concepts in a consolidation phase.

There have been other studies on science inquiry in Singapore classrooms suggesting that primary science teachers’ instructions remained predominantly didactic with only a handful exhibiting science as inquiry practices as described in the curriculum documents (Tan & Tan, 2014, cited Tan and Wong (2012) and Kim, et al., 2013). It was noted by Tan and Tan (2014) that in primary school classrooms the pace of teaching is dictated by the imperative to complete all the workbooks that accompany each textbook and instructions are focussed on drill and practise to train students to produce the correct answers. However, Zhin and Tan (2015) argued that, for the successful practice of scientific inquiry, there needs to be shift from teaching which is directed by teacher to one that is more student-directed. Primary science teachers are usually trained as generalists with no specialised academic training in science. Therefore, teachers need help in this area.

Tan, Talaue & Kim (2014) investigated the views of 41 in-service teachers from five public schools in Singapore (teaching primary 3- primary 6), to find out how teachers experienced teaching science by inquiry under the current educational landscape that is
routinized and highly teacher-fronted (p.111). In their study five features of inquiry adapted from NRC (1996) were used for coding results from surveys. The coding was conducted based on five features of inquiry: (a) learner engages in scientifically oriented questions; (b) learner gives priority to evidence in responding to questions; (c) learner formulates explanations from the evidence; (d) learner formulates explanations from the evidence and (e) learner communicates and justifies explanations. The findings from the study revealed that 38.1% teachers gave greatest attention to (b) evidence in responding to questions, about 21.6% teachers gave priority to (d) learner formulates explanation from the evidence and 7.2% teachers gave least priority to (c) explanation from evidence. Tan et al., (2014) reflective writing and group discussion from the same study found that:

Many teachers held the view that students were not ready to participate in inquiry teaching because the approach was new to them. Having been accustomed to teaching that provided “model answers” in preparations for examinations, students could be expected to resist teaching that emphasised self-discovery and independent learning. (p.122)

Analysis of teachers’ reflections showed that 14.8% of teachers’ concerns were about understanding of inquiry. For example, teachers do not have enough experience or training of how to use inquiry in the classroom because there is a lack of knowledge on how to teach or facilitate inquiry (p.123). 15.8% of teachers revealed that there is insufficient time (about four 30- minute periods per week) for teaching science; heavy content in the curriculum to complete; teachers emphasis content knowledge to gear students for the exam and “addition of inquiry worsens the situation” (p.123). 12.6% teachers feel they have no time for preparation and they also lack available resources. It is, therefore, evident that although teachers are aware of the benefits of inquiry-based instruction, they are not prepared enough to translate this awareness into their actual
classroom practice. This would imply that teachers need training, time, resources and change more than simply adopting teaching methods that have been proven to be ineffective.

With science as inquiry being the pervasive theme in many schools science curricula in Singapore, teachers are encouraged to practise inquiry as a goal as well as a way of teaching science (Tan et al., 2014). It is the responsibility of teachers to “learn new teaching roles, learn how to put students in new roles and foster new forms of student work” (Anderson, 2002, p.8). The Ministry of Education (MOE, 2009) stated that “Teachers play a critical role in preparing their students to thrive in an increasingly complex, competitive and inter-connected world. To do this, they need to deliver holistic education that is increasingly flexible and customised, so as to equip their students not just with content knowledge, but also with the necessary skills and values.”

The Teacher’s Network serves as a catalyst and support for teacher-initiated development through sharing, collaboration and reflection. It also includes learning cycles, teacher-led workshops, conferences and a well- being programmes, as well as websites and publications for sharing knowledge (MOE, 2014). This national paradigm shift has redefined the role of teachers. Teachers needed to constantly look out for new ideas and practices, and continuously refresh their own knowledge. The recent changes to the science syllabus present a new challenge to teachers.

**The Singapore Science Syllabus**

The Singapore government introduced a new primary science syllabus, which was designed to be more inquiry-centric, stating that ‘central to the curriculum
The science curriculum in Singapore undergoes a 6-year review cycle. In 2008, a new science curriculum was rolled out. The Singapore science syllabus does not provide a specific definition of inquiry teaching. Instead it recognizes that the inquiry approach used is dependent on the teaching goal such that ‘student-directed inquiry will provide the best opportunities for cognitive development and scientific reasoning’, while ‘teacher-guided inquiry can best focus learning on the development of particular science concepts’ (Ministry of Education, 2014, p.17). The Science Curriculum Framework in Singapore, shown in Figure 3 was derived from the Policy Framework for the Teaching and Learning of Science. It encapsulates the drive of science education in Singapore to prepare students to be sufficiently adept as effective citizens, able to function in and contribute to an increasingly technologically-driven world (MOE, 2008). As stated on the MOE website (http://www.moe.gov.sg/):

Central to the science Curriculum Framework is the inculcation of the spirit of scientific inquiry. The conduct of inquiry is founded on three integral domains of (a) Knowledge, Understanding and Application, (b) Skills and Processes and (c) Ethics and Attitudes. These domains are essential to the practice of science. The curriculum design seeks to enable students to view the pursuit of Science as meaningful and useful. Inquiry is thus grounded in knowledge, issues and questions that relate to the roles played by science in daily life, society and the environment.
The above MOE statement corresponds closely to the U.S. National Research Council’s (1996) *National Science Education Standards*:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of how scientists study the natural world. (p.23)

According to the curriculum framework which is designed by the Ministry of Education (MOE, 2008) teachers are expected to play the role of leader in inquiry, to make their students independent thinkers, and enhance their problem-solving skills. According to the MOE this will enable students to sustain interest in science and prepare them for the knowledge-based economy in the 21st century. Through examples, classroom discussion and science visits, it is evident that the learner and educators can use inquiry to learn how to do science experiments, learn about the nature of science and learn science content (NRC, 2001, p.15). The success of implementing an inquiry-based approach to teaching and learning in a classroom requires that teachers be familiar with both the nature of scientific inquiry and inquiry-based learning and implement such practices in their classrooms (Anderson, 2002).
Inquiry-based learning may be characterised by the degree of responsibility students have in posing and responding to questions, designing investigations, and evaluating and communicating their learning (student-directed inquiry) compared to the degree of involvement the teacher takes (teacher-guided inquiry). Students will best benefit from experiences that vary between these two inquiry approaches (MOE, 2014, p.13). Teachers in Singapore are encouraged to use a variety of strategies to facilitate the inquiry process. For example, for skills and processes: “In the primary science syllabus teachers are encouraged to provide opportunities for students use concepts and integrate skills and processes to inquire things and phenomena around them.” (MOE, 2008, p.7) Table 2 presents lists the following eleven skills for the process of science.

Under this framework, teachers are advised to be facilitators and role models of the inquiry process so as to encourage and challenge students to develop their sense of inquiry.

However, recent research has shown that teaching and learning approaches are typically not centered around the student as an inquirer (Zhai, Jocz, & Tan, 2014, p.558). Teachers were reported as having dilemmas and difficulties with scientific inquiry (Kim et al., 2013).
Table 2: Description of skills and process listed by MOE (2008, p.7).

<table>
<thead>
<tr>
<th><strong>Skills</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing</td>
<td>This is the skill of using our senses to gather information about objects or events. This also includes the use of instruments to extend the range of our senses.</td>
</tr>
<tr>
<td>Comparing</td>
<td>This is the skill of identifying the similarities and differences between two or more objects, concepts or processes. This skill easily teachers can use in the garden and exhibit galleries.</td>
</tr>
<tr>
<td>Classifying</td>
<td>This is the skill of grouping objects or events based on common characteristics.</td>
</tr>
<tr>
<td>Using apparatus and equipment</td>
<td>This is the skill of knowing the functions and limitations of various apparatus, and developing the ability to select and handle them appropriately for various tasks.</td>
</tr>
<tr>
<td>Communicating</td>
<td>This is the skill of transmitting and receiving information presented in various forms - verbal, pictorial, tabular or graphical.</td>
</tr>
<tr>
<td>Inferring</td>
<td>This is the skill of interpreting or explaining observations or pieces of data or information.</td>
</tr>
<tr>
<td>Predicting</td>
<td>This is the skill of assessing the likelihood of an outcome based on prior knowledge of how things usually turn out.</td>
</tr>
<tr>
<td>Analysing</td>
<td>This is the skill of identifying the parts of objects, information or processes, and the patterns and relationships between these parts.</td>
</tr>
<tr>
<td>Generating possibilities</td>
<td>This is the skill of exploring all the alternatives, possibilities and choices beyond the obvious or preferred one.</td>
</tr>
<tr>
<td>Evaluating</td>
<td>This is the skill of assessing the reasonableness, accuracy and quality of information, processes or ideas. This is also the skill of assessing the quality and feasibility of objects.</td>
</tr>
<tr>
<td>Formulating hypothesis</td>
<td>This is the skill of making a general explanation for a related set of observations or events. It is an extension of inferring.</td>
</tr>
</tbody>
</table>
In summary, all science teachers should have a strong, broad-based foundation to understand inquiry learning and know how to use the skills and processes of scientific enquiry. The current Singapore science syllabus is developed on inquiry-based learning, which requires teachers to use inquiry methods in their teaching. Inquiry also applies to the activities of students in which they develop knowledge and understanding of how scientists study the natural world. Inquiry-based learning may be characterised by the degree of responsibility students have in posing and responding to questions, designing investigations, and evaluating and communicating their learning. Teachers in Singapore are encouraged to use a variety of skills and strategies to facilitate the inquiry process by observing, comparing, classifying, communicating, predicting and evaluating. The Ministry of Education also encourages teachers to focus on group work, emphasis on understanding of concepts, activities based on variety of sources. Teachers should facilitate an interacting learning environment for the students, and teachers should seek to understand student learning.

There is, however, an emergent need to understand teachers’ roles during science instruction, especially when they are crafting an inquiry-based lesson. To assist in providing inquiry-learner experiences, the Ministry of Education has supported a series of Science Enrichment Programmes in Science Centre Singapore.

Science Enrichment Programmes

The Science Enrichment Programmes consists of series of enrichment workshops that were started in 1997 to complement formal science learning and teaching in schools. Conducted at Science Centre Singapore during the school terms, these enrichment workshops include laboratory courses, lectures, demonstrations,
science talks, gallery teaching, guided tours, mathematical problem-solving activities, observatory sessions and computer courses. Dairianathan and Lim (2014) stated “the centre receives more than one million visitors annually of which more than 250,000 are students who come to learn science through informal, hands-on and inquiry based activities. A series of specialised laboratories and workshops provide for a wide range of enrichment programmes for students to complement the schools’ ‘formal science education’ (p.253-254). The Science Enrichment Programmes involve activities that are designed to supplement and/or reinforce formal classroom instruction. They offer learning experiences that are “above and beyond” the formal school curriculum and are non-evaluative and non-competitive (Caleon and Subramaniam, 2007). The number of school groups attending these at the Science Centre is increasing yearly.

Singapore is reputed to have the most comprehensive range of structured Science Enrichment Programmes among all the science centres in the world (Tan & Subramaniam, 2003a). As evident from Figure 4, the number of participants has grown from year to year. The financial year\textsuperscript{10} 2013/14 shows students numbers attending Science Enrichment Programmes reaching a record high of 248,641. Figure 4 illustrates how the number of students who attended Science Enrichment Programmes has increased over the years.

\textsuperscript{10}A financial year is the year for taxing or accounting purposes. Science Centre Singapore’s financial year is from April 2014-March 2015
The Science Enrichment Programmes provide opportunities for students to learn science beyond the confines of the classroom, in a fun and enjoyable way. The programmes are specially designed to connect to what teachers are required to teach in the classroom and aim to complement and support the school’s science and mathematics curricula. These programmes are tailored to schools from pre-primary right up to undergraduate level. A wide variety of programmes including topics from physics, chemistry, mathematics, life sciences, DNA, kitchen science, engineering, astronomy, digital media and robotics, constitute the enrichment courses. Programmes are conducted in the form of lecture demonstration, talks, and hands-on laboratory classes (including hands-on activities in the Ecogarden), talks and nature walks. Through these programmes, learning can take place anywhere in the exhibition galleries, specialized science laboratories, the outdoor Ecogarden, the observatory, and the Omni Theatre. Teachers can select a topic according to their own needs and interests related to the syllabus.
The Science Enrichment Programmes are broadly categorised into the following categories:

- Lab-based workshops, which refer to hands-on classes and are normally held in the laboratories for a class-sized group of students;
- Lecture demonstrations which refer to demonstrations that usually conducted in lecture theatres, which can accommodate a bigger audience;
- Gallery pathways which includes visits to the permanent exhibition with an accompanying worksheet and visits to the temporary exhibitions with accompanying educational programmes.

Teacher surveys and interviews (i.e. Science Enrichment Interview Report, 2006; Science Enrichment Evaluation Report, 2007) revealed that the main reasons offered by teachers for using Science Enrichment Programmes were that this kind of activity and style of learning were not offered by schools due to lack of resources and expertise. Most of the Science Enrichment Programmes were hands-on, the programmes were closely related to the school syllabus, their content was relevant and up to date on current issues on science, and they were entertaining as well as engaging. The survey (Science Enrichment Evaluation Report, 2007) showed that teachers utilised the Science Enrichment Programmes at the Science Centre to complement classroom teaching.

As it is important for the Science Centre Singapore to ensure that its Science Enrichment Programmes are relevant to students and teachers, a nationwide survey was conducted in 2005 (Anthony, 2008). The feedback gathered from 130 primary school teachers and 108 secondary level teachers indicated that visits to the Science Centre Singapore were planned to complement science lessons. Recently, teacher feedback was
obtained from 274 teachers attending the DNA enrichment programme with their students in 2011/2012 (Dairianathan & Lim 2014). All (100%) teachers found that lab and hands-on activities were helpful for the students. 99% of the teachers found that the DNA enrichment programme stimulated their students’ interest in science. Other components from the programme they found helpful were, clear instructions: from the science educator that the programme was connected to the syllabus and teaching approaches.

**Summary of studies at Science Centre Singapore concerning Science Enrichment Programmes**

In Singapore, since the 1970s, only five studies have been done on Science Enrichment Programmes at the Science Centre Singapore. (Dairianathan, 2010; Anthony, 2008; Caleon & Subramaniam, 2005; Lam-Kan, 1985). The study by Lam-Kan (1985) focused on general science and revealed that “participation in science enrichment activities which were meaningfully related to familiar topics would facilitate the development of science interest and improve science achievement by students”. The study by Caleon and Subramaniam (2005) evaluated attitudes and evaluation of programmes relating to low temperature physics, focused on the impact of cryogenics enrichment programmes in Snow City, which is also part of the Science Centre Singapore. Later, Anthony (2008) found that high technology exhibits in the Science Centre Singapore, stimulated interest and learning among students. Recently, Dairianathan (2010) evaluated that the Science Enrichment Programmes in the Science Centre Singapore can foster understanding and interest in life sciences among students. All these studies were focused on students’ participation in the Science Enrichment
Programmes. There has not been a any study to date investigating the teachers’ learning or their role in the Science Enrichment Programmes.

Science Enrichment Programmes at Science Centre Singapore are highly structured. They are focused on students but little attention has been given to the teachers who accompany their classes. Given the emphasis on inquiry learning in Singapore, and the importance of the teacher’s role in such learning, it is pertinent to examine the effect of these programmes not only on the effect of these programmes on the students, but on the teachers as well. Do the programmes enhance the teachers’ understanding of inquiry methods? The Science Enrichment Programmes provide a suitable environment to investigate the nature of teachers’ incidental learning in informal, out of school, programmes targeted at students. This investigation is the subject of this thesis.
Introduction

Research design is a logical sequence that connects the generated empirical data to the initial research objectives of the study and ultimately to its conclusions (Yin, 1994). The success and validity of any research critically depends on the appropriate selection of research methods (Steele, 2000; Fellows & Liu, 2003). This chapter describes the planning and procedures undertaken in the present study. It explains the research approaches used, gives an overview of the research design, outlines the data collection and sampling procedures, and discusses the ethical considerations in this research.

Overview of Research Procedures

The methods adopted to investigate teachers’ learning in the present study were based on a combination of quantitative and qualitative approaches, resulting in what is known as mixed or combined methods research (Spicer, 2004). Pragmatism is often associated with mixed methods research (Creswell, 2003), and given the practical nature of this study it was considered a suitable methodology. The quantitative and qualitative research methods were combined to support and complement one another so as to elicit answers to the research questions.

Qualitative research involves research procedures that do not rely on statistical methods to reach their findings but rather observe the subjects in a natural setting (Merriam,
This type of research primarily uses observation techniques and interviews to gather data. As Strauss and Corbin (1990) have explained:

By the term qualitative research we mean any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification. It can refer to research about a person’s lives, stories, behaviour, but also about organizational functioning, social movements, or interactional relationships…researchers gather data by means of interview and observation – techniques normally associated with qualitative methods. (pp.17-18)

Researchers believe that in many cases qualitative and quantitative research can be effectively combined in the same research project to get better results (see, for example, Strauss and Corbin, 1990; Patton, 1990). Where quantitative researchers seek causal determination, prediction, and generalization of findings, qualitative researchers seek instead illumination, understanding, and extrapolation to similar situations. Qualitative analysis results in a different type of knowledge than quantitative inquiry. For example, Russek and Weinberg (1993) used both quantitative and qualitative methods and claimed that their study of technology-based materials for the elementary classroom gave insights that neither type of analysis could provide alone. Furthermore, an approach which utilises these two methods combines insight, depth, and an appreciation for differences with consistency, predictability, and the ability to generalize broadly (Diamond, Luke & Uttal, 2009).

A Modified Grounded Theory Approach

For the purposes of the present study, the researcher adopted a modified grounded theory approach. Glaser and Strauss (1967) defined grounded theory as “the discovery of theory from data systematically obtained from social research” (p.2).
Grounded theory encourages the use of data from various sources to inform the research methods. A more detailed of grounded theory by Strauss and Corbin (1990) states that:

A grounded theory is one that is inductively derived from the study of the phenomenon it represents. That is, it is discovered, developed and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon. Therefore, data collection, analysis and theory stand in reciprocal relationship to one another. (p. 23)

The present study adopted a modified grounded theory approach by systematically using data to inform subsequent stages of the research. For example, survey responses in the first stage of the study were used to determine subsequent interview methods, and analysis of interview transcripts provided the basis for participant observation in the final stage of the study.

A key feature of grounded theory is the simultaneous collection and analysis of data using a process known as constant comparative analysis. Using this process, data were transcribed and examined for content immediately after their collection. This provided a set of codes that reflected the main themes that emerged from the data. Following this, the data were grouped together on similar dimensions and categorised under suitable names. This modified grounded theory approach allowed the researcher to recognise newly emerging themes from the data, for example the teachers’ survey and interview responses.

While a modified ground theory approach allows for data from multiple methods, the present study did not use triangulation, which is a strategy often associated with qualitative research methods. The decision not to triangulate across the surveys, interviews and observations in the present study was based on literature that criticises the calculated use of triangulation to legitimise research findings (see, for example,
While these critics support the sequential use of multiple methods, they emphasise there needs to be a consistent methodological perspective. The supplementary research questions in the present study provided one such perspective. As Greene and McClintock (1985) state, triangulation should not be confused with multiple methods that are “deliberately interactive, not dependent, and are applied singly over time so that they may not be measuring the same phenomenon” (p.525).

**Research Questions**

**Overarching Research Question**

The following overarching research question underpinned the research methods in the present study:

**Do primary school teachers learn from attending Science Enrichment Programmes designed for the students at the Science Centre Singapore? If so, what is the nature of their learning?**

**The Science Enrichment Programmes**

The Science Enrichment Programmes comprise formal learning experiences provided within informal learning environments at the Science Centre Singapore. Schools are required to book in advance, and there is usually a long waiting list due to the popularity of these programmes. The Science Enrichment Programmes are conducted in purposefully designed indoor and outdoor learning environments, known popularly as *labs*, at the Science Centre Singapore. Each Science Enrichment Programme has duration of one to two hours, and is offered from Monday through Friday and Saturday mornings, with the exception of public holidays. Most Science
Enrichment Programmes are conducted in the first half of the day (i.e. commencing at 9.30am or 10.00am), while some commence at 2.30pm.

On arrival at their respective labs, a science educator takes charge of the whole class which includes the teacher and students. Usually science educators divide the class into groups and direct them to the seating arrangements. There are no designated special seats for teachers and they can sit according to their own convenience. The science educator decides the content, delivery method and skills of the lesson being taught. In this environment, the teacher is a part of the class and observes closely the ways in which the class is being taught, and at the same time may take part in the activities for the students that are conducted by science educator. The teacher follows the instructions of the science educator just as the students do.

The Pilot Study

A pilot study was conducted, from June 2011 to July 2011, to address the overarching question and to establish whether teachers learn in the Science Enrichment Programmes. Accordingly, an ethics application was prepared, explaining the research procedures and methodology to the ANU Human Research Ethics Committee. Ethics approval for the present study was obtained in September 2011.

Accordingly to the literature, pilot studies, which are sometimes referred to as preliminary studies, are a crucial step in the research process. For example, Van Teijlingen and Hundley (2001) suggested a list of reasons for conducting pilot studies, which include:
developing and testing adequacy of research instruments; assessing the feasibility of a full-scale study/survey; designing a research protocol; assessing whether the research protocol is realistic and workable; collecting preliminary data; assessing the proposed data analysis techniques to uncover potential problems; developing a research question and a research plan.” (p.2)

The goal of a pilot study was to explore the answer to the overarching research question. Accordingly, the pilot study in the current research used a survey to ascertain the views of the teachers who attended the Science Centre Singapore with their students and to find out whether teachers learn in the Science Enrichment Programmes. A second purpose for the pilot study, prior to the formal research phase, was to obtain the teachers’ views and to frame supplementary questions for the final study, consistent with the modified grounded theory approach.

The Pilot study survey questions were developed and designed in consultation with the research supervisors at ANU. The validity of the pilot study survey questions was subsequently checked and modified with scholarly input from the academic skills and learning support services for research students at ANU. The pilot survey questions focused on the teachers’ perspectives about learning during the Science Enrichment Programmes (see Appendix, III). To this end, the teachers were asked if the information provided to them was new, and if it was, how they would use it in their classroom:

\begin{itemize}
  \item \textit{Was any information provided in the programme new to you?}
  \item \textit{If any of the information was new, will you use it in your classroom teaching?}
\end{itemize}

\textit{Sample}

The pilot study survey was carried out at Science Centre Singapore for 60 primary school teachers from the schools that are under the Ministry of Education. The
teachers were selected from classes listed in a weekly schedule of Science Enrichment Programmes from the first week of June 2011 to the end of July 2011. The survey was conducted with teachers who came for 14 different types of Science Enrichment Programmes during that period. Each teacher was approached at the end of the programme to take part in the survey, given their prior consent. Each survey took around 10-12 minutes to complete.

The pilot study confirmed, at a broad level, that teachers do learn while accompanying their students to the Science Enrichment Programmes – thus affirmatively answering the overarching research question. However, the pilot study did not provide a detailed picture of what elements of the Science Enrichment Programmes enabled teachers to learn, or precisely how they participated in the learning process, or how they subsequently integrated their learning into their professional knowledge base. To understand the nature of teachers’ learning in the Science Enrichment Programmes, the two following supplementary research questions were developed based on the modified grounded theory approach. The two supplementary research questions framed the main investigations of this research by enabling deeper insights into the teachers’ learning during the Science Enrichment Programmes:

**Supplementary Questions that framed the main study**

1. **How the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?**

2. **How do teachers integrate that learning into their classroom practice?**
To answer these questions three methods were chosen for the main study in this thesis. They are described in the following sections.

**Stage 1: Survey**

**Stage 2: Interviews**

**Step 3: Observations.**

**The Main Study - Stage 1: Survey**

In the first stage of the main study, a survey was carried at the Science Centre Singapore with the teachers who accompany their students for the Science Enrichment Programmes. The most important part of the survey process was the creation of questions that accurately measure the opinions, experiences and behaviors of the teachers. To conduct these surveys ethical approval was approved by ANU in the year 2011. Important elements emerging from these surveys will be discussed in the subsequent chapters of this thesis.

**Why Surveys?**

Surveys offer one of the best ways to access subjective information and to generate a large amount of data for analysis and interpretation (Stewart, 2002). This method of data collection was chosen for the present study due to its suitability for collecting comprehensive and detailed information from primary school teachers attending the Science Enrichment Programmes. They enabled the researcher to investigate at a deeper level about primary school teachers’ learning during the Science Enrichment Programmes.
The questions for the main survey were redesigned from the pilot survey and were discussed with the supervisors. From the pilot survey, few questions were added, deleted and modified before the final survey was administered to the teachers. For example, the focus of surveys was narrowed down from pilot study (14 programmes) to only three Science Enrichment Programmes offered by Science Centre Singapore. The researcher focussed on: *viz. Aquatic plants and animals, Diversity of cells, and Light.* These Science Enrichment Programmes are part of the suite of programmes offered by three different locations at the Science Centre (see Table 3). The main reason for selecting these programmes was their popularity, as shown in Figure 5.

Table 3: Information about chosen Science Enrichment Programmes

<table>
<thead>
<tr>
<th>No</th>
<th>Science Enrichment Programmes</th>
<th>Location at Science Centre</th>
<th>School Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aquatic plants and animals</td>
<td>Eco Garden</td>
<td>Primary 5 – 6</td>
</tr>
<tr>
<td>2</td>
<td>Diversity of cells</td>
<td>DNA Lab</td>
<td>Primary 5 – 6</td>
</tr>
<tr>
<td>3</td>
<td>Light</td>
<td>Physics Lab</td>
<td>Primary 4</td>
</tr>
</tbody>
</table>
Figure 5. Participant numbers for chosen Science Enrichment Programmes shown in blue followed by next popular Science Enrichment Programmes in that location shown in red. (Source: Science Centre Singapore, Unpublished data 2010).

The Survey

The questions for the main survey were redesigned from the pilot survey and were discussed with the supervisors. From the pilot survey, few questions were added, deleted and modified before the final survey was administered to the teachers. A survey including both closed and open ended questions was created to identify teachers learning for the Science Enrichment Programmes. The first part of the survey consisted of 12 multiple choice questions, which asked teachers about their background; i.e. their tertiary education, the subjects they taught in school, their teaching experience, previous visits to the Science Centre Singapore and the purpose of those visits (see Appendix, V). A pair of open ended questions was added to the survey to find out the teachers’ opinion about co-learning with their students during the Science Enrichment Programmes:
Data Collection

A sufficient sample of primary school teachers was necessary to ensure that the results were representative of the total population under consideration. Therefore, 120 teachers were chosen from Primary Levels Four, Five and Six. The survey was carried out over a period of 20 weeks, starting in September 2011 and concluded at the end of February 2012. Surveys were distributed to teachers accompanying school groups that visited the Science Centre during that period from schools belonging to the Ministry of Education in Singapore. Teachers were invited to complete the survey at the end of the Science Enrichment Programme. The teachers were provided with a consent form (see Appendix, IV) which they completed before commencing with the survey.

Each teacher took approximately 10 minutes to complete the survey. At the end of each survey, the teachers were requested to indicate their consent to be interviewed for the second stage of the study and the contact details of consenting teachers were recorded for future use.

Data obtained from the survey were analysed using SPSS and the results are presented in Chapter 4. Teachers' responses to the open-ended questionnaire were compiled and the content analysed by categorising the responses. Similar responses were combined and general category descriptions were subsequently developed. The modified grounded theory approach was used to identify themes from the survey responses and then transfer those themes to develop questions for the interviews.
The next stage of data collection comprised interviews with consenting teachers who participated in Stage 1 of the study. The interview method was used here to explore and investigate at a deeper level about primary school teachers’ learning during the Science Enrichment Programmes. The teachers were individually interviewed face to face in their own schools. Important elements emerging from these interviews will be discussed in the subsequent chapters of this thesis. The findings that are highlighted in these discussions have been collectively drawn together in the final chapter to answer the second supplementary research question about how teachers integrate their learning in classroom practice.

**Why Interviews?**

Interviewing is a technique of data collection that involves gathering information about what people think and feel from their perspectives, by asking relevant questions (Patton, 1990). Interviews are the most common and one of the most appropriate data gathering tools in qualitative research (Mason, 2002; Merriam, 1998; Rubin & Rubin, 2005, p.vii), and involve construction and reconstruction of knowledge (Mason, 2002, p.63).

The researcher selected interviews as an appropriate method for this phase of the studies. First, the researcher was in direct contact with the teachers, this gave an opportunity to the researcher for follow-up questions and verification of answers that helped to increase the validity of the data (see, for example, Denscombe, 1998; Newman & McNeil, 1998). Second, the information conveyed was insightful, in-depth, and from the teachers’ point of view. Third, the interviews provided an opportunity for
the researcher to investigate ideas and beliefs of the teachers further, and enabled the gathering of data which may not have been obtained by surveys only (see, for example, Cohen, Manion & Morrison, 2000; Shaughnessy, 2007). Lastly, the researcher used this technique to help bring the structures and meanings that were often hidden from direct observations to the surface (as described by Hatch, 2002, p.91). According to Dexter, (1970, p.136) person-to-person interviews can be defined as a conversation but - a ‘conversation with a purpose.’ The main purpose of the interview is to find out what is “in and on someone else’s mind” (Patton, 1990, p.278):

We interview people to find out from them those things that we cannot directly observe.... we cannot observe feelings, thoughts, and intentions. We cannot observe behaviours that took place at some previous point in time. We cannot observe situations that preclude the presence of an observer. We cannot observe how people have organized the world and the meaning they attach to what goes on in the world. We have to ask people questions about those things. The purpose of interviewing is to allow us to enter into the other person’s perspective (Patton, 1990, p.196)

For the purpose of the present study, the Interviews about Instances technique was used to find the answers for the second supplementary question.

**Interview about Instances**

A number of interview strategies has been developed for use in qualitative research (Southerland, Smith & Cummins, 2000). However, in the present study the Interview about Instances technique was adapted. This technique, initiated by Osborne and Gilbert (1980) and developed further by White and Gunstone (1992), is possibly the most widely used format for probing understanding about single concepts. According to White and Gunstone (1992), “an interview about an instance is a conversation that an expert has with one student, focused by initial questions about situations represented in a series of line diagrams, to check the student’s interpretation of a natural phenomenon
or social occurrence (p.65).” White and Gunstone used this technique to study the understanding of primary and secondary students for concepts in physical sciences, such as electric currents. Revealing one drawing at a time, the student was asked to indicate whether it depicted an example of the concept in question, and to provide a justification. The technique showed instances which provided an initial stimulus to generate a conversation.

The Interview about Instances technique was chosen for the present study due to its suitability for collecting comprehensive and detailed information from primary school teachers about a single event – the Science Enrichment Programme. It was also intended to allow for the researcher to set up a free flow of information. Interviews were, therefore, planned with guiding questions complemented by pictures of the selected Science Enrichment Programmes (see pictures, Appendix X, XI, and XII). The teachers’ responses were investigated further with the help of probing questions (see Hatch, 2002; Patton, 2002).

The interview framework included 27 open-ended questions, guiding questions and visual prompts, and pictures from the Science Enrichment Programmes, consistent with the Interview about Instances technique (see pictures, Appendix X, XI, and XII). Open-ended questions were used as a template for the interviews because they allowed respondents freedom in their answers and the opportunity to provide in-depth discussion (see Wimmer & Dominick 1994, p.110). The interview protocol questions were based on the results from the final surveys. The interview guide protocol (see Appendix, VIII) was discussed with the supervisors and subsequently reviewed and modified by the researcher from the feedback received from them. The researcher identified which
questions will be asked, and how each question should be asked. The researcher was advised by the supervisors to choose the questions which will help to elicit detailed information from the teachers. For example, the researcher was advised to use probing and clarifying follow-up questions, as necessary, to gather complete information. An interview question guide was used during the interview to ensure that all required information was captured during the interview and that the topic of conversation remained relevant and consistent throughout. The researcher took notes of relevant information and the interviews were transcribed verbatim.

Audio recordings of interviews allowed for the researcher to directly quote the teacher and to re-read the transcript during the process of writing. The supervisors listened to three interviews, and their comments were used to modify the interview protocol. For example, the supervisors advised on the interview technique:

*You can also try "affirmation" as a means of positively encouraging the teachers to talk; for example, "That is a very interesting view, tell me more about..." or "That is a very important point, so tell me then how did the Enrichment Programme help you to ...", etc.*

They pointed out the following as well:

*I listened to your recent interview with Mr X (pseudo name). You conducted the interview excellently and did well to probe further. I encourage you to practise probing the teachers' responses with "how", "why" "what did you feel like"-type of questions.*

The supervisors also commented on the clarity and value of particular questions and addressed on suitable changes, for example, comments included:

- *It is not clear what you mean by Question 8, if not necessary delete it;*
- *Change order of Question 12 and 13 (reverse their order);*
One supervisor attended sample interview A19, in the capacity of an observer, in order to monitor and provide feedback after the sample interview was completed.

**Sample**

Interviews commenced in November 2011 and ended in the last week of April 2012. Of the 120 teachers who participated in Stage 1 surveys, 100 teachers expressed consent to be interviewed. 60 of these teachers were selected on a first to consent basis for Stage 2 interviews. They comprised 20 teachers each from the Science Enrichment Programmes Aquatic plants and animals, Diversity of cells, and Light. An appointment was made with each teacher and they were contacted via phone, or in some cases via emails according to their preferred mode of communication as indicated in the survey.

The teachers were provided with an information sheet (see Appendix, II) together with consent form (see Appendix, VI), which they completed before commencing with the interview. With permission granted, interview sessions were audio recorded for subsequent analysis.

All interviews were conducted in these teachers’ schools during their school break or after school hours. For convenience and for a suitable environment for the interview sessions, the teachers made bookings at libraries, laboratories, or staff rooms with a view to ensuring places that allowed freedom of expression as far as possible. Each interview lasted up to 45 minutes.
Data Collection

At the beginning of the interview, each teacher was presented with one picture from the Science Enrichment Programmes which they attended at Science Centre Singapore with their students a few months earlier (see Appendices X, XI, & XII). The teachers were then asked to recall and reflect their learning experiences by looking at those pictures. They were asked to describe the most important instance they recalled from the Science Enrichment Programme. For example, a lesson on “Aquatic Plants and Animals” showed pictures of the Eco garden, ponds, students looking through a microscope, students with nets catching animals, collecting plants from the ponds as well as pictures of micro-organisms.

The questions were structured to ensure room for teachers to elaborate about their learning in the Science Enrichment Programmes, with the aim of exploring concepts that the teachers associated with a particular experience. This process was facilitated through open-ended probing questions to extend the teachers’ answers and gain more in-depth understanding. Three types of probing questions were used which were identified by Patton (1990). These were, detail-oriented probes (for example, “When did you come for this class?”); elaboration probes (for example, “Can you tell me more?”); and clarification probes (for example, “Can you give me an example of what you are talking about?”).

At the end of each interview, the teachers were presented with a matrix to identify the types of knowledge they believed were conveyed during the Science Enrichment Programmes (see Appendix IX). The matrix was created on a five point scale based on Barnet and Hodson’s Pedagogical Context Knowledge model (2001), where 1 indicated
“very little” and 5 “a lot”. According to Barnet and Hodson, the ideal teacher uses four kinds of knowledge:

1. Academic and research knowledge
2. Pedagogical content knowledge
3. Professional knowledge
4. Classroom knowledge

**Transcribing**

All Interviews were transcribed. Each transcribed interview was analysed individually. Each of the 20 teachers from three Science Enrichment Programmes was given a matching alphabet code (i.e. L-Light, D-Diversity of cells, & A-Aquatic plants and Animals) and a consecutive serial number from 1 to 20. These identification codes were entered according to the date that the interview was conducted. For example;

1. Aquatic plants and animals, (A) (A 1, A 2...A 20)
2. Diversity of cells, (D) (D 1, D 2... D 20)
3. Light (L) (L 1, L 2... L 20)

The present study used an inductive approach in which data was analysed using a modified Grounded Theory approach (Strauss & Corbin, 1998). The main purpose was to search data to answer research question. All 60 interviews were transcribed and tabulated on excel sheet according to teachers’ response to each question. The codes emerged from the data via a process of reading and thinking about the text material. The important points from teachers’ responses from transcribed interviews were highlighted with different colour codes. The procedure involved a process in which the researcher chose to code words, important segments, or other portions of text so that the researcher
can group and compare similar or related parts of information. About 300 to 400 codes emerged from the data which was later organised into 15 to 20 categories and subcategories. These categories were again grouped into five to seven concepts or themes. The key concepts reflected the meaning attached to the data which was collected. These emergent themes were tested through observations.

The researcher often highlighted codes to distinguish concepts and categories. For example, if interviewees consistently talk about teaching methods, each time an interviewee mentions teaching methods, or something related to a teaching method, the researcher highlighted that word with the same colour. Teaching methods would become a concept, and other things related (types, etc.) would become categories – all highlighted in the same colour.

**The Main Study - Stage 3: Observations**

In the final stage of the main study, the observation method was used to explore and investigate at a deeper level about primary school teachers’ learning during the Science Enrichment Programmes. It must be mentioned here that the researcher purposefully reserved observation of the teachers’ participation in the Science Enrichment Programmes for the third and last stage of this study. This was to ensure that the Stage I surveys and Stage 2 interviews, in the main study, were not influenced by observer-bias, which may have resulted if the researcher observed the Science Enrichment Programmes at the beginning of this study. It was intended, therefore, that observation of teachers’ learning during the Science Enrichment Programmes would offer insights that were unlikely to have been gained from the surveys and interviews alone.
Observation can reveal behaviour that participants take for granted and fail to report in self-report methods, and can disclose information that participants are reluctant to share in the interviews (Patton, 2002). As Patton (1990) stated, observation data enables a researcher to gain a comprehensive understanding of the situation being described when this tool is used to observe teachers in a real learning environments:

The purpose of observational data is to describe the setting that was observed, the activities that took place in that setting, the people who participated in those activities, and the meanings of what was observed from the perspective of those observed. (p.202)

Cohen, Manion and Morrison (2005) have stated that observation as a strategy presents opportunities “to gather ‘live’ data from ‘live’ situations” (p.305). Additionally, observations give first-hand information about social processes that other sources are unable to reveal adequately (Silverman, 2006), as well as assisting researchers to explore nonverbal expressions, such as feelings (Schmuck, 1997). Observation can cast light on interaction among participants and on individual behaviour, in a way that questionnaires and even group interviews or focus groups do not (Cohen et al., 2007). Therefore, an important feature of observations in the present study was that it provided the researcher with first-hand data about teachers’ actions and interactions during the Science Enrichment Programmes.

*Why Observations?*

Observations were chosen for the study because they include descriptions of the participants, descriptions of the physical settings, and accounts of particular events and activities (Bogdan & Biklen, 1998). Just like interviews, observation can present a more accurate picture of reality (Cohen et al., 2007) and allow the researcher to witness certain patterns of teacher behaviour which were not possible during the interviews.
Observations are considered to be a tool to collect data “when it is systematic, when it address a specific research question, and when it is subject to the checks and balances in producing trustworthy results” (Merriam, 2009, p. 118). First, observations allow researchers the opportunity to document behaviour as it occurs in a certain setting, thus, making observations a first-hand source of information in comparison to interviews. Observations involve all of the senses. They include what one hears, sees, smells, tastes, and feels. They are the “aha” moments of noticing. They are feelings inside you that emerge.

They provide researchers with ways to check for nonverbal expression of feelings, determine who interacts with whom, grasp how participants communicate with each other, and check for how much time is spent on various activities (Schmuck, 1997). In this case, it also facilitated the researcher to observe interactions of teachers during the programme and to understand how students, teachers and science educators communicate with each other which was not possible from surveys and interviews. Conducting the study in a natural setting allowed the researcher to observe teachers in their "real life" environment.

According to Morrison (1993, p.80), during observations, a researcher gathers data on:

a. The physical setting (e.g. Physical environment and its organisation)

b. The human setting ( e.g. the organization of the people, the characteristics to make up of a groups or individuals being observed, for instance gender, class)

c. The interactional setting (e.g. interactions that are taking place, formal, informal, planned ,unplanned, verbal,-non-verbal etc)
d. The *programme setting* (e.g. the resources and their organisation, pedagogic styles, curricula and their organisation).

For the purpose of the present study, the *Participant observation technique* was used to find the answers for the **second supplementary question**.

**Participant Observation Technique**

A number of observation strategies have been developed for use in qualitative research. However, in the present study the *Participant observation technique* was adapted. Dewalt and Dewalt (2002) believe that "the goal for design of research using participant observation as a method is to develop a holistic understanding of the phenomena under study that is as objective and accurate as possible given the limitations of the method" (p.92). They suggested that participant observation be used as a way to increase the validity of the study, as observations may help the researcher have a better understanding of the context and phenomenon under study. Marshall and Rossman (1989) add that this research method allows the researcher to immerse in the settings and “hear, see and begin to experience reality as the participants do” (p.79). Hence Wolcott (1988) points out, depending on the purposes of the study, the role of the observer could assume that of an *active participant* to a *limited observer*. For the purposes of the present study, the researcher assumed the latter role (*i.e.* a complete observer). This meant that the author “observed without participating” (Creswell, 2003) in the Science Enrichment Programmes.

Before the actual observations were done for the present study, the researcher accompanied the supervisors from ANU to Questacon - The National Science and
Technology Centre in Canberra in the month of October 2012, to watch and observe science shows. The purpose was to observe what presenters were saying and doing during their science shows. This opportunity enabled for the supervisors to ensure that the researcher was given the chance to witness various scenarios and how the presenters were communicating with each other and with the audience. Notes that were taken by the supervisors and the researcher were compared to see if the right ideas and observations were made.

**Sample**

Observations, in the present study, proceeded from analysis of interview data, where the key learning points from the interviews were used to frame the observation guide (see Figure 6). A separate sample of nine primary school teachers was observed when they attended the Science Enrichment Programmes with primary students at the Science Centre Singapore. Care was taken to ensure that they were not among the samples of teachers in Stage 1 surveys or Stage 2 interviews, previously, in order to ensure validity of the research findings. The respective programmes for observation were selected from a weekly schedule of the Science Enrichment Programmes from the first week of January 2013 to the end of March 2013. Observations were restricted to the three previously identified the Science Enrichment Programmes (Aquatic plants and animals; Diversity of Cells, & Light).

The main focus during the exercise was to observe the teachers during the Science Enrichment Programme; i.e. to understand how the teachers actually engaged in this environment. Particular attention was paid to their interactions and communications with the students and the science educator. Each observation lasted for the duration of
the Science Enrichment Programme; i.e. about 2 hours. The researcher was a participant observer, assuming the role of a full covert member of the group, and focused mainly on the teachers’ actions.

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**Observation Guide**

Observations were made in the Science Centre Singapore, to address and match the key themes that the teachers addressed and explained during the interviews. A structured observation guide was developed based on the key learning points which emerged from the interview data. The observation protocol was then designed, clarified, modified and finalized with the supervisors at ANU (see Figure 6). The observation guide included, for example, qualitative descriptors of a teacher’s position at the beginning of the lesson, the teacher’s movement and position during hands-on activities, specific interactions with the students, specific interactions with the presenter, and the emotional behaviour of the teacher during the lesson (see Appendix XX, XXI and XXII).
Figure 6: Observation Guide for the Science Enrichment Programme.
Recording Observations

The observation guide (see Figure 6) recorded variables, such as, the positioning of the teacher during different stages of the Science Enrichment Programmes, how the teacher interacted with the students and the science educator during various Science Enrichment Programme activities, also to which elements of the Science Enrichment Programmes the teacher paid special attention, for instance taking photographs, making notes, etc. The variables that were included in the observation protocol were independently validated by my supervisors.

Analysis of Data

The researcher grouped and categorized the observations according to the teachers’ interactions with the science educator; interactions with the students; their involvements with the hands-on activities; as well as their emotional behaviours, such as their facial expressions, and body language throughout the Science Enrichment Programmes. Repeating patterns were grouped together into coherent categories and assessed subsequently.

Figure 7 has captured the three stages of data collection in the present study. It provides an overview based on the Overarching Research Question and the two Supplementary Research Questions that Developed from the Pilot Survey.
**Overarching Research Question:** Do primary school teachers learn from attending Science Enrichment Programmes designed for the students at the Science Centre Singapore? If so, what is the nature of their learning?

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**Supplementary Research Questions**

**Supplementary Research Question: 1**
How do teachers integrate that learning into their classroom practices?

**Supplementary Research Question: 2**
How does communication of science enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

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**Stage 1: Survey - 120 Teachers**
Survey Results to Inform Interview Questions

**Stage 2: Interview - 60 Teachers**
Interview Results Influence Observational Variables

**Stage 3: Observation - 9 Classes**

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**Figure 7:** Flowchart Showing Stages of the Research Process.

In the following chapter, the researcher presents the results from the different research methods that the researcher have described here.
Chapter Four

Results

Introduction

This chapter describes the pilot study and the major survey that were conducted for the Science Enrichment Programmes. The pilot study was important to find out whether primary school teachers do learn during the programmes designed for the primary school students at the Science Centre Singapore. A second purpose for the pilot study, prior to the formal research phase, was to obtain teachers’ views and to frame supplementary questions for the final study. Thus the initial study helped to frame the supplementary research questions:

1. How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

1. How do teachers integrate that learning into their classroom practice?

The Pilot Study

The pilot study was carried out with sixty primary school teachers from Singapore schools which fall under the Ministry of Education. The teachers were selected from a weekly schedule of the Science Enrichment Programmes from the first week of June 2011 to the end of July 2011. The study was conducted for the teachers who come for all different types of Science Enrichment Programmes. There were 14 different types of programmes during that period. Each teacher was approached at the end of the Science Enrichment Programme. After getting their consent to take part in the study, each survey took around 10-12 minutes to complete (see Appendix III). The
survey consisted of 12 closed and open-ended questions. Teachers’ teaching experience in primary schools is shown in Figure 8.

![Figure 8: Teachers’ teaching experience in primary schools (Pilot Study).](chart)

The survey showed that out of 60 teachers, 26 teachers have more than 10 years of experience. Few had less than one year’s teaching experience.

Teachers were asked in the study whether this was their first visit to a Science Enrichment Programme. Eighty percent of teachers reported that they had attended the Science Enrichment Programmes more than four times in the past five years. Twenty percent reported that this was their first visit because their teaching experience in the school was only one year.

They were also asked to which topics they preferred to bring their students for the Science Enrichment Programmes. From the results obtained from the survey (Figure 9) it can be seen that most teachers wanted to attend topics related to physics, biology and DNA.
What was the purpose of teachers in accompanying students to attend the Science Enrichment Programmes?

Nine options were given to the teachers in the pilot survey to find out why they bring their students for the Science Enrichment Programmes. The nine options were:

1. The lesson is related or connected to the school syllabus
2. To complement the classroom science lesson
3. To enthuse students about science and technology
4. Because these programmes are easy to understand
5. To give students hands on experience
6. To make learning interesting
7. To get new ideas for teaching
8. Because of lack of such facilities in the school
9. Other…
The results revealed (Table 4) that 16% of teachers prefer programmes which give their students hands on experience, make learning interesting or are related to the syllabus. In addition 15% of teachers showed preferences for the programmes which complement their science lessons. Fewer teachers chose programmes on the basis that there were easy to understand, or to get new ideas. Therefore no single reason can be given for teacher support for the Science Enrichment Programmes.

Table 4: Purpose of bringing students to attend for the Science Enrichment Programmes (Pilot Survey)

<table>
<thead>
<tr>
<th>Activities</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lesson is related or connected to the school syllabus</td>
<td>16%</td>
</tr>
<tr>
<td>To complement the classroom science lesson</td>
<td>15%</td>
</tr>
<tr>
<td>To enthuse students about science and technology</td>
<td>13%</td>
</tr>
<tr>
<td>Because these programmes are easy to understand</td>
<td>7%</td>
</tr>
<tr>
<td>To give students hands on experience</td>
<td>16%</td>
</tr>
<tr>
<td>To get new ideas for teaching</td>
<td>8%</td>
</tr>
<tr>
<td>To make learning interesting</td>
<td>16%</td>
</tr>
<tr>
<td>Because of lack of such facilities in school</td>
<td>9%</td>
</tr>
<tr>
<td>Other</td>
<td>0%</td>
</tr>
</tbody>
</table>

Teachers who accompanied their students for the Science Enrichment Programmes had majored in diverse subjects (Figure 10). These included English, Chemistry, Biology, Mathematics Sociology, Geography, Marketing, Sports, Social Sciences and Arts. The largest groups were in English and Maths.

Finally, the teachers were asked, “If information in the Science Enrichment Programmes is new, how would you apply that information in your school?” Twenty three percent of the teachers said they have lasting impressions in their mind and that
they apply knowledge learned from the Science Enrichment Programmes in their school. They recap and reinforce what they have learned, back in the classroom. Nineteen percent reported that they would use this as an enrichment activity in their school, while four percent responded that they would apply the learning as extension activities and they would ask students to further research on the topic and present it to the class. Fifteen percent explained that they would create similar demonstrations in the class. Eight percent of teachers feel that it was a good programme for higher ability classes. The remainder of the teachers 31% percent did not comment.

![Figure 10: Primary school teachers’ education background (Pilot Study).](image)

From the results of the pilot study, the researcher gained a clear vision of the research topic, the questions, and the methods, which were applied later in the study. The pilot study also allowed identification of confusing and unclear questions that were addressed in the stage one surveys. For example, from the pilot study it was revealed that teachers prefer lab lessons as compared to lecture demonstrations. Based on the pilot survey, questions for the final survey were refined and three Science Enrichment Programmes were chosen for the survey.
The Main Study - Stage 1: Survey

This section describes the second survey that was conducted for the primary school teachers who accompany their students for the Science Enrichment Programmes. The main survey followed the analysis of the pilot survey, in which it was confirmed that primary school teachers learn when they bring their students for the Science Enrichment programmes. The supplementary research questions addressed in the survey were:

1. How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

2. How do teachers integrate that learning into their classroom practice?

Survey data were recorded for the three Science Enrichment Programmes chosen for the study (viz. Light, Diversity of Cells, & Aquatic Plants and Animals). A total of 120 teachers, 40 from each of the Science Enrichment Programmes, were given the survey at the end of each Science Enrichment Programme. All surveys were conducted at the Science Centre Singapore and teachers were chosen randomly from the weekly schedule of the Science Enrichment Programme. This survey yielded very similar demographics to the pilot survey (Figures 11 and 12).

Out of 120 teachers, 41 teachers had more than 10 years of experience. Results indicate that the more experienced teachers, in terms of number of years taught, are more likely to bring their students for the Science Enrichment Programmes.
Figure 11: Teachers’ teaching experience in primary schools (Main Study).

Figure 11 indicates that, as for the pilot survey subjects, they were not all science teachers. The teachers who attended the Science Enrichment Programmes come from English, Chemistry, Biology, Mathematics, Sociology, Geography, Marketing, Sports, Social Sciences and Arts. As mentioned in the literature review, most primary school teachers teach multiple subjects including Languages; Arts, Mathematics, Social Studies, and Science (Davis & Smithey, 2009). In this case, some of the teachers who attended these programmes do not have a science background. The largest groups (35%) were from an English or Maths background. Less than half of the teachers in the survey had a science background, across different areas of science. It is obvious from the data that many primary school teachers will have limited knowledge of the subject matter as reported by Anderson and Mitcher (1994). Such teachers will continue to require many forms of support to overcome these problems.
What was the purpose of teachers in accompanying students to attend the Science Enrichment Programmes?

Nine options were given to the teachers during the second survey to find out why teachers bring their students for the Science Enrichment Programmes. The nine options were:

1. The lesson is related or connected to the school syllabus
2. To complement the classroom science lesson
3. To enthuse students about science and technology
4. Because the programmes are easy to understand
5. To give students hands on experience
6. To make learning interesting
7. To get new ideas for teaching
8. Because of lack of such facilities in the school
9. Other…

Figure 12: Primary school teachers’ education background
The results revealed (Table 5) that 87.5% of teachers prefer programmes which complement their classroom teaching and give students hands on experience. In addition, 85% of teachers showed a preference for programmes which were related to their school syllabus. Fewer teachers selected programmes on the basis of easy understanding or to get new ideas. Most of the teachers preferred hands on experience because according to them they cannot provide these learning opportunities in their school.

Table 5: Purpose of bringing students to attend the Science Enrichment Programmes (Main Survey).

<table>
<thead>
<tr>
<th>Activities</th>
<th>Number of Responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lesson is related or connected to the school syllabus</td>
<td>102</td>
<td>85.0%</td>
</tr>
<tr>
<td>To complement classroom science lesson</td>
<td>105</td>
<td>87.5%</td>
</tr>
<tr>
<td>To enthuse them about science and technology</td>
<td>71</td>
<td>59.2%</td>
</tr>
<tr>
<td>Because the programmes are easy to understand</td>
<td>35</td>
<td>29.2%</td>
</tr>
<tr>
<td>To give students hands on experience</td>
<td>105</td>
<td>87.5%</td>
</tr>
<tr>
<td>To make learning interesting</td>
<td>98</td>
<td>81.7%</td>
</tr>
<tr>
<td>To get new ideas for teaching</td>
<td>43</td>
<td>35.8%</td>
</tr>
<tr>
<td>Because of lack of such facilities in the school</td>
<td>51</td>
<td>42.5%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

The nature of the content of the programmes

Teachers were asked to indicate in the survey whether information gained in the Science Enrichment Programmes was new. Results (Figure 13) show that 47.50% of teachers found the information was new. 36.67% of teachers found some of the information was new, and 15.83% of teachers did not find the information new at all.
From these results, it is clear that even though these programmes are designed for the students, the majority of teachers gain information that is new for them.

![Bar chart showing responses to the question: Was the information new to you?](chart13)

Figure 13: Information provided in the Enrichment Programme for the teachers.

The teachers were asked whether they would apply this information in their school; the majority again indicated agreement as shown in Figure 14.

![Bar chart showing responses to the question: If new, will you use in the classroom?](chart14)

Figure 14: Teachers intent to applying new information in their school.
The majority (59.32%) indicated that they would apply all the new information in their classroom teaching, while 22.88% said they would apply some of it. The teachers who said ‘no’ were asked to explain their reasons: These teachers were mostly from the Science Enrichment Programme on light. According to these teachers, they do not have dark rooms in their schools so they cannot apply the same knowledge. Other teachers’ responses were that they would use this knowledge as enrichment, as a follow up activity, to revisit what students had learned and to use some of the demonstrations to introduce the lesson in the school.

The teachers were asked to identify how the Science Enrichment Programmes differ from their school programmes.

![Figure 15: How Science Enrichment Programmes differs from schools.](image)

The Results from Figure 15 show that most of the teachers find learning facilities and teaching resources at the Science Centre different from school. Teachers mentioned that these facilities are not available in their schools. Twenty two teachers also found the methods of teaching different from school.
Figure 16: Are teachers and students co-participants in the learning process?

One of the most important questions asked of the teachers was whether they considered themselves co-participants with their students in the Science Enrichment Programmes.

Q.12: Do you agree that teachers and students are co-participants in the learning process?

Q.13: Why do you feel that way (as stated in your answer above)?

Out of 120 teachers who took part in the surveys, 112 agreed with this statement (Figure 16). Just seven teachers agreed to some extent, and only one disagreed.
Following this question, teachers were asked to give reasons for their agreement. This was the last question in the survey, and was open ended. Out of 120 surveys, 100 teachers responded to this question. After analysing 100 responses similar responses were grouped into four categories, based on the reasons the offered by the teachers (Figure 17). According to the teachers, co-participation in the Science Enrichment Programmes learning experience was due to:

- Gaining new information,
- Learning together,
- Learning about students, and
- Learning constantly.

**Gaining new information**

Results showed that 43% of the teachers gained new information by attending the Science Enrichment Programmes with their students. Since the information was new to both them and their students, the teachers perceived this as co-participation. The
teachers indicated this new knowledge was about new strategies, discovering new things together and gaining new ideas during the programmes. In order to demonstrate the common basis for grouping the teachers’ responses under this category, a sample of relevant responses to survey Q.13 are provided below:

As teachers, we learn new things and new ways of teaching when they sit in during the Enrichment lesson.

Some of the information provided by the instructors may be new to us teachers and we learnt some new teaching styles from the instructors.

The experience enforced certain new concepts, and gave new ideas.

I learnt how to bring knowledge and application of concepts to students.

As teachers, we get to gain new insights in the Enrichment programme.

The Enrichment programme gives us another perspective - multiple perspectives/methods of interpreting the same content, all unique to individual learning styles.

**Learning together**

About 32% of teachers said that they learned together with the students, as students were the main participants in the learning process. It was a kind of mutual learning, where both groups conducted experiments together and both learned at their own pace. Some of their responses included statements that related to the previous category; i.e. gaining new information:

We both learn together new concepts, new information, experiments, new knowledge, new ideas, and new things; new ways of teaching investigations.

Something new can always be learned, be it either pupil or teacher.

The teachers’ responses also described listening to the same instructor as the students in the Science Enrichment Programmes, which are student-centric. In order to demonstrate
the common basis for grouping the teachers’ responses under this category, a sample of relevant responses to survey Q.13 are provided below:

*The Enrichment program allows the teachers to have a common learning experience with pupils.*

*Although the lessons are catered to children, as a teacher I learned new things too - even clearing some misconceptions.*

*It is shared learning which is effective for both groups: a two-way communication.*

*Both parties, teachers and students, are continuously learning at a different level; both are participants in the learning process.*

**Learning about students**

About 18% of responses indicated that teachers learn *about* their students in the Science Enrichment Programmes. Teachers have an opportunity to observe their students in these programmes and see what their students are learning so they can build on what their students have learned. One responses stated, for example:

*Teachers should take this opportunity to learn as well. At the same time teachers can assess the programme from the point of view of students.*

They have the opportunity to see how their students get motivated, their weaknesses and their strengths, and how to convey knowledge and application of concepts to their students. They observed which type of questions students asked during the investigation and in many cases these questions opened a new line of thinking for the teachers. In order to demonstrate the common basis for grouping the teachers’ responses under this category, a sample of relevant responses to survey Q.13 are provided below:

*Sometimes students pointed out somethings not observed in the classroom, such as that some students learn better when teachers are in the role of facilitator.*

*There are multiple observations about students depending on what a pupil sees and does.*
Students’ questions open a new line of thinking in us teachers.

During the Science Enrichment Programmes teachers had the opportunity to be closer to their students and the connections between teacher and students were strengthened.

Learning constantly

About 7% of teachers mention that they constantly learn. From the above results, it became clear that the Science Enrichment Programmes, that are conducted for students may provide an equally important learning experience for the teachers as well. In order to demonstrate the common basis for grouping the teachers’ responses under this category, a sample of relevant responses to survey Q.13 are provided below:

Learning is never ending, it can take place when we as teachers sit in the lessons with our students.

Learning does never stop.

There are always new things to pick up.

Teacher’s participation and learning will role model to students the importance of being a lifelong learner.

The conclusion was that the teachers’ role is not only that of an instructor, but a guide and facilitator. These different roles are explored in the interviews, which are described in the next section.

The Main Study - Stage 2: Interviews

This section describes the results from the interviews that were conducted with primary school teachers. The aim of the interviews was to explore and investigate a deeper understanding of primary school teachers’ learning during the Science Enrichment Programmes designed for primary school students. In order to conduct an
in-depth investigation of this primary research question, answers to the following supplementary questions were sought:

1. **How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?**

2. **How do teachers integrate that learning into their classroom practice?**

Teachers demonstrated that they gained and learned about different types of knowledge along with the students. Based on the responses from these interviews, four major themes emerged from the data analysis. These four main themes that emerged from the interviews are:

   a. **Content Knowledge**
   b. **Classroom Knowledge**
   c. **Personal/Professional Knowledge**
   d. **Pedagogical Content Knowledge**

To illustrate these themes, excerpts from teacher interviews are included in this chapter. Many of these quotes are complex and reflect more than one theme. Rather than reduce the thematic quote to a single sentence, the teachers’ voices are presented in their multiplicity of contexts to illustrate the repetitive nature of the themes and the rich discussion which occurred during the interviews. For example, Teacher Number A20 commented that:

> I have a physics background but some of the primary teachers don’t even have a science background. Lessons become interesting to learn if content is related to the syllabus. In lessons, for example on “Aquatic plants and animals”, we were introduced to habitat, different types of aquatic plants, animals, their adaptations and food chains. We were able to learn so many things about the plants and animals. We were given background information on plants and animals that was very useful to me. I enjoyed the activity since we were actively
involved in it and at the same time we learned in depth about the content of the lesson. Now, when I teach this topic, I am very confident.

In the above quote, the teacher illustrates problems arising from the lack of science background knowledge, the importance of syllabus-based content, the nature of active learning in the programme, the in-depth learning which occurred, and increased confidence that ensued. These aspects are subsumed within the four main themes, mentioned previously, and will be discussed in this chapter.

Content Knowledge

Content Knowledge is the “knowledge about the actual subject matter that is to be learned or taught” (Mishra & Koehler, 2006, p.1026). Content knowledge includes knowledge of the subject and its organising structures (Grossman, Wilson, & Shulman, 1989; Shulman, 1986b, 1987; Wilson, Shulman, & Richert, 1987).

Teachers repeatedly demonstrated that one of the types of knowledge which they acquired during the Science Enrichment Programme was content knowledge. According to them, it is important for them to understand the content they are going to teach. Teachers explained that a better understanding of the concepts of science in these programmes gave them additional knowledge which they could bring to their classroom teaching. They commented that, as teachers, their main job was to convey science concepts to students and to ensure that they communicate these concepts in a way which helps their students to understand and learn better. Teachers pointed out that they themselves learned about some concepts from the Science Enrichment Programme, especially in the case of some of the abstract concepts of which they did not have
sufficient knowledge, because they did not have an opportunity to come across such concepts when they were students themselves and later even as teachers.

The following sub-themes emerged from my analysis of the interview data, and these will be discussed in the section that follows:

- Teachers are not expert in content knowledge
- Teachers learned content in depth
- Content was easy to understand and was related to syllabus
- Content was based on the learning environment and the resources in that environment

**Teachers are not expert in content knowledge**

Teachers stated that they are not expert in teaching all science subjects. According to them, primary school teachers are not sufficiently prepared to teach science effectively as they often lack science content knowledge. This perception of the generally inadequate preparation of teachers was also pointed out by Garet et al (2001); Penuel. Fishman,Yamaguchi and Gallagher (2007).

Teachers stated that they are not expert in teaching science as they do not have the requisite knowledge of inquiry-based science lessons needed to teach reform-oriented science. The National Centre for Education Statistics (2001) also noted that primary school teachers are inadequately prepared to meet the learning needs of diverse students. This further adds to the struggle they face in simultaneously addressing science content knowledge when teaching their students (Lee, 2005). The views of Teacher A5 on the issue are reproduced below:
I am not a biology teacher, my background is engineering. I was grateful that I accompanied my students for this lesson. I appreciated nature in the Eco-garden, how plants and animals are adapted to live in that habitat. I learned a lot of things about plants and animals. I learned that a pond is a fascinating habitat to study lots of things, with a great variety of both plants and animal life: how to categorise them, how to differentiate between floating, submerged and partially submerged plants. I learned that one pond was quite different from another even if two ponds are close together. Also the water temperature, oxygen content, water quality have an influence on the animals in the pond. I saw a diversity of plants and animals in natural surroundings. I saw the colours, sizes, and shapes which you cannot find in the books. I found out that in any pond it is important that there is a balance of different kinds of organisms so that there is enough food for them all to live and reproduce.

The most important thing which I learned was that a wide variety of plants and animals would indicate that a pond is healthy. Content knowledge that I gained about the pond life was a systematic collection of information. It is very helpful for me to apply in my classroom.

Teacher Number L5 revealed that:

Attending this workshop helps me in making the classes more educational and also helps in setting examination questions. I majored in English and thus for teachers like me, I really learned lots of things from this programme and I feel confident to teach this topic. I think when teachers know their subject well, they feel confident. As a teacher when you are confident you are able to communicate well with your students.

Teacher Number L5 went on to say:

I attended this programme for the first time and I learned a lot because in Enrichment Programmes, they cover a lot of interesting facts like ‘who discovered cells’. I learnt how to how to carry out lessons. The lessons we have in the Science Centre cannot be carried out in our own schools. Thus, the learning experience is different in the Science Centre and in schools. Resources here cannot be compared with the school. They actually make learning very engaging, interesting and by attending this workshop, it helped me in making the classes more educational and also helped in setting examination questions.
Teachers learned content in depth

Teachers demonstrated that by accompanying students they learn about science content knowledge in detail and in depth. They added that the amount of knowledge required for a certain topic should not just be restricted to the boundaries of the syllabus, but it should also go further and include other areas as well. These additional insights would not only help to provide a context to the topics and help to explain certain concepts easily, but it would also be interesting and understandable and would be incorporated and communicated during teaching in schools. As stated by Bybee and Stage (2005) lack of teacher content knowledge is a limiting factor in raising student achievement. Teacher Number L3’s views on the issue are reproduced below:

The Enrichment Programmes are excellent and by attending the programmes with students, I learned new ways of exploring how the students are thinking about the content and concepts being taught. There was a focus on the subject matter that was taught, for which the students had to do a hands on activity on the same topic. Basically, in these programmes there was the idea of us getting to know the science concepts - all the interesting things we wouldn’t show in the class. What comes to mind are interesting pictures, images… it is a holistic approach. Enrichment wise, I think I learned content in depth outside the text book in what we have covered.

Teacher Number D2 also stated that content was taught in depth, in other words, if content knowledge is not identified as being valuable it may be lost. She explained:

Attending the Enrichment Programme with students was an eye opener for me to get the content knowledge in depth. In school, when I used to show a plant cell to the students, I was not able to show and explain different parts of a cell. Here in this lesson I came to know and learn the structure of a plant cell. Earlier I thought a chloroplast is one lump in the leaf, and it stays still in the cell, because in our books and even in our teaching aids it is shown like it doesn’t move - but in the Enrichment Programme “Diversity of cells” I saw it under microscope. The chloroplast was not stationary it was moving within a cell. Then the instructor made it clear that the chloroplast is moving in the cytoplasm. It was a wow thing for me. It is really hands on, for me and for my students to see real cells and things we cannot see with our naked eye. It interests the students and teachers as well. I also learned a new term: moving of chloroplasts is called cytoplasmic streaming.
The data also revealed that many primary teachers have incomplete understanding of science concepts as mentioned by Rennie (2006), and many teachers will need to broaden their content knowledge to enable them to bring contemporary science into the classroom (p.22). Teacher Number A13 explained:

*This environment [is one] I cannot produce in school - of course, because it is a totally hands on experience. It is important that students get to see and touch real things. Of course, I don't think all the teachers supposed to teach this topic know exactly what animals and plants look like. If they come here and experience, learn what children are experiencing and learning, they will be actually better off explaining things back in school.*

**Content was easy to understand and was related to syllabus**

Teachers commented that they had an opportunity to learn content that is directly related to the syllabus that is taught in schools. The content of the subject includes the facts, concepts, principles or laws that have been gathered through decades or centuries of inquiry into the subject. They mentioned that in science, content grows and changes with new research findings as well as new theoretical developments, just as in literature it expands with new pieces of literature and it changes with new interpretations of existing pieces. In the Science Enrichment Programmes the content goes beyond the syllabus. Teacher Number L4 commented that:

*Content is relevant to my students learning as it is part of the syllabus. The Science Centre has more enrichment-type lessons and these interest the students and us and makes them know about what the learning process means.*

*There are some concepts that are difficult to explain and learn through books and explain to students. Because of the limitation of resources, we are unable to demonstrate to students certain concepts and it can only be explained to them theoretically. Bringing them to the Enrichment Programmes and allowing them to see things - how science actually works - can really excite them. The kind of equipment and apparatus used, kinds and design of experiments, make students see the practical part of science that is mostly lacking in schools. In*
schools we always talk about assessments, we talk about teaching and completing the syllabus.

Garet et al., (2001) also stated that teachers must learn more about the subject they teach and more emphasis should be given to understanding the subject matter. Teacher Number L9 stated:

*I remember: angle of incidence is equal to angle of reflection. They [students] took time to understand. OK in school we don’t get this opportunity of hands on experiences. When they go there and do experiments themselves they get excited. It drives the concept deeply into their minds. They can understand rotation of the light, otherwise it is very flat in the book. I was happy because we were able to understand this topic a better way.*

Griffin (1999) reported that the contribution of teacher education is becoming a powerful lever for change in schools. It is for this reason that science teachers should be well prepared in their teacher preparation programmes. The following comment was made, for example, by Teacher Number A8:

*“Aquatic plants and animals”: I was able to answer some questions raised by students. Different varieties of aquatic plants in the Eco-garden: that is eye opening to me, I am not a biology person. But I learned in depth about specific content [concerning] different types of aquatic plants and animals. Besides this, teachers require the knowledge of how to deliver that subject content knowledge which their students can understand during teaching process. Textbooks do not focus on some of the concepts. Yes, I think it is beyond the book knowledge we have as usually, in books, certain concepts are not explained in detail and it would be difficult to understand.*

Some teachers appeared to rely heavily on textbooks, failing to realise the benefits of constructivist learning. According to Ball and Cohen (1999), teachers need to have in-depth understanding of meanings and connections in subject matter and not just procedures and isolated information. Teacher Number A1 explained that:
When you teach from the books, that book is written by one or two persons, in that book it is the way author thinks, and how to elaborate that concept depends on that person. In the Enrichment Programme we have actual firsthand experiences and recourses to learn, also different teaching styles. Primary school students are visual learners, sometimes it is very difficult to explain concepts that are very theoretical. Certain concepts, for example about different types of cells and plants and animals, are very difficult to explain. Sometimes some of the concepts are not explained in the text books. I learned how to explain and demonstrate concepts to the students.

Feldman (2000) states that teachers need to make sense of scientific knowledge in ways that are personally meaningful to them. This means that scientific information should seem “reasonable” in terms of being “understandable, sensible, beneficial…and be in tune with the teacher’s goals” (p.612). When teachers perceive science content knowledge to be relevant to their own interests, it becomes easier for them to “negotiate meaning within the learning community, make connections with past personal understandings, (and) modify prior conceptions if they are inaccurate” (Anderson & Michener, 1994, p.2).

Content was based on the learning environment and the resources in that environment

The teachers being interviewed noted that the environment was conducive to learning and was quite different from their school environment. They said that they would like to visit more often so that they can learn things they themselves did not understand. Teachers commented that they do not have equipment to conduct such lessons. Some even said that they do not have a dark-room to conduct experiment with light. The environment provided a different experience for teachers as well as for students. Sometimes there is a new idea as, for instance, about how to be constructivist when teaching a particular concept to the students. Teacher Number L1 explained that:
In school it is theory, very limited experiments. For the light in these programmes [we have] equipment: how to use experiments to see light travels in a straight line. What we see in textbooks we don’t grasp so well as when we saw actual things. When we see actual things we internalize [and] they learn. And we are also able to understand that the angle of the incident ray is the angle of reflection. Such concepts are cleared here. It was a very fruitful experience for me because here we are able to see how the colours are formed and how they merge. I learned how, by shining a torch light at an angle at the mirror and I also drew the lines. These are visual experiences which I will use in my teaching.

Teachers felt that actual specimens and objects were helpful in learning content so that they did not have to depend on pictures in the text books. The "hands-on" activities encourage learners to be actively involved in the learning process, sharing ideas with their peers and developing responsibility for their learning. In addition, the lessons which are interactive with firsthand experience are important for promoting the learning of scientific concepts. Teacher Number A11 explained:

There are many real specimens that we came across during the lesson and it is always good for teachers to get away from the everyday school classroom and experience and learn from a lesson with a difference, which we experience in the Enrichment Programmes. I was able to see, feel and touch the specimens that made learning more exciting, meaningful and easy to understand concrete concepts.

For instance, putting animals into context - that is, how they interact with the environment - raises environmental awareness and the learners are thus able to think holistically. They also learn to be observant by looking at the plants and animals in more detail and reflecting on their physical structure. Teacher Number L3 was fascinated to gain insights into how student learn. She stated:

This means that learning becomes meaningful, when learning is within the context and made relevant to the learners' everyday lives, and this calls for the contextualisation of the curriculum in schools. I also learned in light lessons about the conservation of light and how to impart content knowledge about light to the students.
This view is consistent with Geddis (1993), who points out that:

In order to be able to transform subject matter content knowledge into a form accessible to students, teachers need to know a multitude of particular things about the content that are relevant to its teachability. (p.676).

According to teacher Number L19:

*In science it is more hands on, to really see it and feel it. Most of the concepts are clear when you yourself do it. From a text, it does not get into the mind. I remember the activity where we got to see the colours of rainbow. The Instructor actually showed the rainbow by putting a glass of water on the overhead projector. We saw a huge rainbow across the classroom. I like that. It is not easy to create a rainbow in an indoors place. By learning science concepts I can do this in my own class. It should be a dark room, no light. [We learned] properties of light. How light travels in a straight line. The shining of light through different lenses. It is beyond the book knowledge we have.*

Teachers feel that reinforcement of science concepts is important. As Teacher Number L16 stated:

*I really liked the activity with the prism. The most dramatic activity that I can recall is the shining of the white light through the prism because it clearly shows the students that white light is made of seven colours. The very interesting thing that I could remember is that the instructor was able to show how white light is scattered into rainbow colours and back into white light. The way instructor used those tools to make our concepts clear in an interesting way, which I learned myself as well - he switched off the lights to show colours of lights and it was very distinctive experience for me.*

*I and my students liked the activity where the instructor kept the beaker half full of water on the overhead projector and shone the light on the water, which caused the rainbow on the wall. It was a new thing which I learned, that by shining light on the beaker of water, the concept of a rainbow can be explained. I will go back and use this demonstration while teaching light lessons in the school.*

Data revealed that teachers need to learn certain concepts along with the students so that later, if the concepts are clear to the teacher, it is easier to explain and communicate to the students. The data show that it is easier for teachers to learn *how* to impart learning
in the environment of the Science Enrichment Programmes. To be successful, teachers must have strong subject matter knowledge, understand the nature of science, be able to translate scientific concepts into meaningful learning experiences for their students, and highlight applications for science within society and in the lives of students (Gess-Newsome, 1999). Teachers indicated that these aspects were addressed during the programmes.

Classroom Knowledge

Classroom knowledge is the knowledge that a teacher has of their own classroom and students (Barnett & Hodson, 2001). According to these authors, it is a special type of knowledge which outsiders do not have and cannot possess because it is rooted in their day to day experience of individual educational situations. In the classroom, teachers have the opportunity to observe their students, and teachers adjust their “tone, delivery, activities, verbal interactions, and so on, to ensure that the lesson proceeds as planned” (Barnett & Hodson, 2001, p.439). Thus, classroom knowledge enables teachers to “think on their feet at both a micro and macro level” (p.439). In a much earlier study, Schwab (1971) described teacher knowledge in practical terms as the wisdom of practice developed through classroom experience.

Most of the teachers indicated during the interviews that by attending the Science Enrichment Programmes they learned and enriched their classroom knowledge. By analysing the data obtained from the interviews, the following themes emerged:

- Class setting
- Learning from students working in a group
- Learning from students’ motivation
- Communication and bonding.
Class setting

The findings showed that the class setting is important to teachers’ learning from the Science Enrichment Programmes. The teachers believed and repeatedly demonstrated that a well organised environment in the Science Enrichment Programmes increased teaching and learning outcomes for teachers and students, respectively. The most important discovery was that, because lessons were pitched at the student level, the teachers were able to learn from the students’ point of view. For example, the students pointed out to each other some living creature in the pond during the lesson, something that could have gone unnoticed by the teachers. This finding corroborates the finding of Good and Brophy (2008) who noted that many things go on in the classroom simultaneously even when students seem to be doing only one task together.

Teacher Number D10, who has been teaching in Primary Six for more than ten years, stated:

The Science Enrichment Programmes are very unique because of the lab settings. These settings bring enthusiasm in the students and teachers. I always look forward to bringing students for these lessons. Being a major in physics, I can definitely improve my teaching by looking at the classroom setting and how the science educators teach and interact with the students.

Teacher Number D13, with more than 20 years of experience, recalled that:

I try to book lessons every year because this type of platform is inaccessible anywhere else. The Science Enrichment Programme which I attended was very interesting. Students are much disciplined. Their interests excite me as well. They get to touch and feel the things in addition to what we teach them in a classroom. I think what they were shocked about was when they saw that the chloroplast was able to move. Back in school, they are not able to see that, and here with the excellent magnification it’s easier to see it. Even though, the specimens are similar to those we have in the school, like the hydrilla plant, the quality differs. The microscope used in such classes offers a much clearer and better projection. In school, it is more manual and we have to assist students individually.
These results support the opinion of Little (1993), that teacher learning is more effective when it is closely linked to the teachers’ classroom context. Accordingly, Teacher Number D17 shared that:

_The Science Centre has a variety of Science Enrichment Programmes which I attend every year. I find the class setting and equipment in the class fantastic. This makes learning very hands on and interesting. The environments in which the educational programmes are taught are different as compared to those in a traditional school. I feel that I learn from the class setting, resources and environment and it helps me to learn more enjoyably and wholesomely. I try to do the same thing when I go back to my school._

**Learning from students working in a group**

Teachers revealed that they learn from _and about_ the students during the Science Enrichment Programmes as well. Teachers explained that they learn about how students work effectively in a group and how they ask questions, get motivated and interact with each other. In this way they acquire new aspects of classroom knowledge and are able to explore students’ thoughts about the concepts being taught. During the enrichment classes, teachers have the opportunity to ask students about how they relate science to "real life" personal situations. They usually try to share students’ worldviews and see the scientific ideas from their point of view. Two such examples that emerged from the teachers’ interviews are given below.

Teacher Number D12, a teacher with more than 10 years of experience, stated that:

_I got chances to examine my students during the Science Enrichment Programmes, how my students work in groups. In each and every Science Enrichment Programme, students are supposed to work in groups. I got a chance to learn how educators assign roles in a group and how students arrange themselves to do experiments in a group. When students work in groups, they communicate very well with each other. In a school, we have to focus on the whole class; here our focus is drawn onto smaller groups. The learning depends on the individual lesson. In this lesson, I learned about the diversity of cells and at the_
same time observed how students were engaged and understood the concepts.

Teacher Number D4, with almost 20 years of experience stated that:

*I got a chance to be with the students during the Science Enrichment Programmes and I saw the way different groups of students react to a lesson. I even obtained a chance to see their way of applying the concepts instantly on the spot. These programmes use a real environment to learn in. We can see how much they are learning and the type of questions they ask. Once back at school, we reflect to internalize what students have learned and how they can reinforce the concepts. By looking at the profile of the students..., I will try to plan and conduct more hands on lessons and try to use examples which the trainer used during the lesson.*

This view has been supported by Johnson et al., (1986), who noted that students learn better when they are in groups. Furthermore, learners in groups get the chance to participate actively, to ask questions freely in their own language, to share ideas and to solve problems collaboratively, when group work is employed - provided it is properly implemented. Group work therefore gives students an opportunity to learn from each other through task-orientated activities. This promotes learning and social skills rather than the sole accomplishment of tasks used in traditional approaches to teaching and learning.

In a further elaboration of this point, Teacher Number A17, who has regularly attended the Science Enrichment Programmes, talked about Aquatic Plants and Animals. According to her:

*During the Science Enrichment Programmes, the learner is given the opportunity to work in groups, discuss and share their ideas such as catching animals and identifying plants from the pond identification booklet. By observing students working in a group, teachers learn more about [how] they understand, grasp concepts and the needs of the students. It is important to learn about our students and at the same time ask students for their opinions, hear what they say and accept it.*
Mostly, in the Science Enrichment Programmes, as a teacher, I was able to learn about student responses from what we perceived and this has the potential to value what they actually think or may mean.

According to Milner and Milner (2008), working in groups allows students to generate ideas, use language, learn from each other, and recognize that their thoughts and experiences are valuable and essential to new learning (p.36).

Teachers indicated that students’ opinions help them to provide a more conducive environment for learning. These results reinforce the findings of Etchberger and Shaw (1992) that teachers must constantly be aware of what knowledge each individual learner has and should always strive to make science relevant to the learners’ everyday lives. Therefore, the focus of classroom activities should move from the teacher to a learner-centred approach, recognising that learners do contribute to their own knowledge and to the learning environment.

Furthermore, Abell (2007) noted that, overall, teachers lack knowledge of students’ conceptions. This knowledge improves when teachers gain more experience with their students. Teacher Number L17, who has an immense passion for science, indicated that:

*I learn from every Science Enrichment Programme I attend. I learn because I get a chance to interact with the students and constantly improve myself. Students always ask questions and these forces me to think about various ways to explain the same subject matter. In the school, I am the one who is conducting the lesson.*

**Learning from students’ motivation**

Motivation is a desire, a want, a state of tension or related state that forces people to do something for the accomplishment of some objectives (Hoy & Miskel, 1987). It is an aspiration for the person to engage in some activity. Teachers found that
students are motivated and more engaged in the Science Enrichment Programmes compared with what they do in school. During the interviews, two teachers from the same school (viz. Teacher Numbers D16 and D17) expressed their views about how they motivated by their students:

Teacher Number D17 stated:

_Lab coats, which were provided to the students during these programmes, can play a positive effect and motivate students about science. When students wear lab coats during the DNA programme, they feel proud of themselves. It is more or less the same, but it is the environment that changes the interest of students and teachers as well. When students wear lab coats, they feel they are very important, like a scientist._

Teacher Number D16 stated:

_Students get excited to wear lab coats. This is something different that we don’t have in our school. Beyond that is a science laboratory experience which they have, so what happens here is when they enter the lab, they definitely have first-hand experiences like a scientist and it is a very good start to motivate our young children to become future scientists. In addition, if they are not keen in becoming a scientist, this experience which they have acquired here allows them to continue, pursue other areas of science._

Teacher Number A9 mentioned in the interview that there is constant learning with the students:

_Another thing which I recall by looking at the picture is about mystery game. How it makes the students interested and how science can be taught in a fun way._

Correspondingly, as mentioned by Brookfield (1995):

_The most fundamental metacriterion for judging whether or not good teaching is happening is the extent to which teachers deliberately and systematically try to get inside students’ heads and see classroom and learning from their point of view (p.35)._
Also, Teacher Number A20 shared that:

*I learned that the content of my subject is very relevant, but more important is that students become interested in it, that they themselves are motivated to search for questions and answers. By learning to make lessons interesting, motivating children and evoking their curiosity, we learn at the same time. That was well-reflected with the experience I had. Students saw pink eggs of a snail but they did not know what it was. They thought that it was some kind of weird looking organism. Students took back the eggs to the lab and saw the specimen under a microscope. This evoked their curiosity. It was the instructor who told us that they were actually the eggs of the giant apple snail.*

**Communication and bonding**

Effective science teaching occurs when both the teachers and students learn. Teachers in interviews responded that they get a chance to get closer to students while attending the Science Enrichment Programmes, and noted that such opportunities are lacking in schools. In order to communicate with students, a rapport has to be established to enable teachers and students to learn together. Teachers demonstrated that they communicate with students and learn from the students because the perceptions of students can be extremely informative and helpful to teachers. Students’ inputs are a valuable resource which can help teachers to reflect on their practice and modify it accordingly. For example Teacher Number A9, with twenty years of experience, explained that:

*While catching animals from the pond, I was working together with the students. Students tried to scoop some of the pond water and found many living organisms which were unnoticed by me. I got a chance to communicate with the students on how they actually learn. The learner is central to the process during the workshop. The instructor provides the learner with a service. I enjoyed myself when I saw how my students communicated and learned ways in which science actually works. Even teachers get a chance to observe their behaviours and their enthusiasm in a way. What you see is what you get. Since some of the experiments can be done in the school, teachers learn and retrieve ideas from such programmes. It is a one way to make learning interactive and fun. I look forward to such lessons.*
Also, Teacher Number L2 stated:

_The learning process that they had experienced during the Science Enrichment Programme was the same which my students were experiencing. I was personally in an advantageous position to understand their problems better, and had a closer connection to communicate with the students and producing solutions related to that._

Brophy and Good (1985), indicated that students learn best when teachers spend most of their time focusing on content with learning activities focused on the learner level of understanding, appropriately moving forward and with well-structured and presented material. A student learns more effectively when the teacher structures new information, relating it to prior knowledge of the learner, monitoring the learning and providing effective feedback.

Hamre and Pianta (2001) add that when students feel they have strong and positive relationships with teachers, they are more likely to believe and love the teachers and are more motivated to learn from them.

Students’ interactions with teachers are an important aspect of classroom life. Teachers can look at how students learn to understand each other, how they learn to listen, to immerse themselves in the thinking of peers and teachers, to feel for others’ efforts and to realise that they must express to their own thoughts.

**Personal /Professional Knowledge**

The transcribed data gathered from the teachers’ interviews provided further qualitative evidence in support of personal learning and teachers’ roles during the Science Enrichment Programmes. There was also evidence of increased attainment in terms of the teachers’ perception of their own personal learning. All of the teachers
interviewed commented on this increased personal learning, and attributed this to the teaching strategies introduced in the Science Enrichment Programmes. According to Clandinin (1985) personal knowledge is:

…the knowledge which is imbued with, all that goes to make up a person. It is the knowledge which has arisen from circumstances, actions and undergoings which themselves had affective content for the person in question. Personal knowledge can be discovered in both the actions of the person and, under some circumstances, by disclosure or conversation. (p.362)

Another definition for personal knowledge is offered by Johnson (1989), who states that personal knowledge:

…is meant to focus attention on the way teachers understand their own world, insofar as this understanding affects the way they structure the classroom experience and interact with their students, parents, colleagues, and administrators. (p.361)

Thus having established what the literature states about personal knowledge, the next section will offer insights about what the teachers in the present study perceived with regard to the influence of the Science Enrichment Programmes on their own personal knowledge. By analysing the data obtained from the interviews, the following themes concerning personal/professional knowledge emerged:

- Experiential learning
- The teachers’ role.

**Experiential learning**

The word “experiential” essentially means the learning that is achieved through personal experience through participating and involving, rather than received through teaching or training. The purpose of experiential learning is to create an opportunity for
valuable and memorable personal learning experiences. It is the process of making meaning from direct experience; i.e. “learning from experience” (Itin, 1999).

Experiential learning is especially holistic and it involves and engages the senses of sight, smell, touch, hearing, and possibly taste (Beard & Wilson, 2002). Senses become aware consciously or unconsciously of stimuli filtered by perceptual factors which include previous knowledge, emotions, location and personal needs, where the outcomes of the learning experience are unique to each learner. In essence, “people interact with the world and learn from this experience by processing stimuli received” (Beard, Wilson & McCarter, 2007, p.5). Gentry (1990) further defined this concept as follows:

> Experiential learning is participative, interactive, and applied. It allows contact with the environment, and exposure to processes that are highly variable and uncertain. It involves the whole-person; learning takes place on the affective and behavioural dimensions as well as on the cognitive dimension. The experience needs to be structured to some degree; relevant learning objectives need to be specified and the conduct of the experience needs to be monitored. (p.20)

Teachers demonstrated in the interviews that activities in the Science Enrichment Programmes were real, engaging and not based on artificial impacts. They explained that they like these programmes, because they are mostly hands-on, interactive, fun, and interesting activities for them to learn from and about their students. Teacher Number L2 stated:

> Attending these workshops has been an eye-opener and an empowering experiential learning for me. I personally learned by the experience I acquired there. Experience in the Science Enrichment Programmes arouses some of the feelings, for example: curiosity and interest. The experience can be best conducted by the use of personal experience. The easier you can process an experience, the more you would relate to it and like the experience.
The following definition (Hoover & Whitehead 1975, p.25; as cited in Gentry, 1990, p.10) is also relevant:

_Experiential learning exists when a personally responsible participant cognitively, affectively, and behaviourally processes knowledge, skills, and/or attitudes in a learning situation characterized by a high level of active involvement._

Teacher Number A8, who attended the Science Enrichment Programme -Aquatic Plants and Animals explained his experiences about the programme in the context of a prior misconception:

_I [have been] teaching science to primary six students for the past ten years and this lesson is an eye opener for me. I saw the water banana plant for the first time. I didn’t know it has got two types of roots. I can actually feel and see the roots and experience what they look like. Books’ explanation and real experience are totally different. I remember this personal experience and really I learned a lot from this lesson. This experience I didn’t get while I was studying and even during my training programme for teachers. This type of learning will help me personally, and to communicate clearly the concepts to the students through my teaching._

Teacher Number A11, with more than 20 years of experience stated that:

_In the Science Enrichment Programme the students and I were able to see live animals rather than, in school, pictures from the books. We learn concepts better when we get first-hand experience. As a teacher, I and my students don’t get the chance to catch animals in school. As I am not a major in science I didn’t get this exposure even when I was studying in primary school. It is a different experience in here to make them interested in science. This personal experience helps me to do well in my science class._

Elbaz (1991 & 1983) was one of the earliest contributors to this form of teacher research. He stated that a teacher’s personal knowledge increases with experience. According to him, teachers’ personal knowledge includes more than theoretical knowledge of subject matter and of teaching methods. Teacher Number D17 shared that
he became personally interested and curious in these programmes. When asked what curiosity means to him, the response was as follows:

*I feel that ‘curious’ means finding missing information, in other words it is ‘information-gaps’ which we fulfill here. During these programmes we have to find information ourselves. For example, the mystery game [in the DNA class]. We had to find information ourselves and we were curious. In other words we were fully engaged in the activity. When I see students enjoying [themselves], I also enjoy and learn at the same time. I think it is good for science teachers to attend, this type of lesson. My expectation always is to get a feel of real hands on that we really don’t get to do when we are in school.*

Through experience, teachers develop knowledge that regulates their own teaching (Carter, 1990). Teaching experience also influences the development of teaching skills (Clermont, Borko, & Krajcik, 1994). Teacher Number L16 stated that:

*I feel very enlightened and time spent is worth it with the students. It is lot of hands on, visual experience and what we do in here we don’t do in the school. It is a very enriching experience for us. I guess it is a reminder of my own excursions when I was in primary school - the same activity I came for. Of course it brought back fresh memories of what I learned myself when I was in primary school.*

Elbaz (1983) argues that the teacher’s practical knowledge encompasses firsthand experience of students’ learning styles, interests, needs, strengths and difficulties, and a repertoire of instructional techniques and classroom management skills (p.5). One of the teachers, Number D10, who attended the Science Enrichment Programme - Diversity of Cells, recalled her experience in the following way:

*I remember it was two types of cells. For animal cells, I tried to make a slide of our own cheek cells. We were told to scrape our skin from our cheeks and spread it on the slide. It was a very good experience - we could see our own body cells, how they look. After that, the students and I saw the difference between plant and animal cells. They really can see differences. For example, for the plant cell they saw chloroplasts, as a teacher I also saw all the differences. For example, animal cells do not have a cell wall whereas plant cells do. We saw [that the] animal cell has an irregular shape while the plant cell has a fixed shape.*
The teacher added:

As a teacher, I not only gain knowledge but it is also a form of reinforcement because sometimes, I might have forgotten certain facts but when I come for the enrichment class, I get refreshed and personally I learn lot of interesting facts like ‘who discovered cells’. These programmes add on knowledge to classroom lessons and, in other words, it provides teachers with a new perspective.

The science educator showed me mosquito fern and water moss fern. Both were floating but were different in size and structure. The science educator showed spore bags hanging from floating moss fern, and for mosquito fern the science educator crushed one leaf and showed how this fern has algae (anabana) inside like some beads. It was add-on knowledge which I never came across earlier. When teachers have their personal knowledge about subject matter [increased] they feel confident to teach.

Gentry (1990, p.20) summarised that experiential learning is participative, interactive, and applied. It allows contact with the environment, and exposure to processes that are highly variable and uncertain. It involves the whole-person; learning takes place on the affective and behavioural dimensions as well as on the cognitive dimension. The experience needs to be structured to some degree; relevant learning objectives need to be specified and the conduct of the experience needs to be monitored.

The teachers’ role

A very important result that emerged from the interviews was that teachers’ roles change when they accompany their students during the Science Enrichment Programmes. Teachers mentioned that in schools, they are the main person in charge of managing the class, including the resources required to deliver knowledge to students. They are, therefore, heavily focused cognitively on developing teaching content. They have time only marginally to think about effective pedagogy that would enable them to have greater interaction and communication with the students during the lesson.
However, the teachers generally noted that they do not see themselves as the main person in charge of delivering learning content during the Science Enrichment Programmes in the Science Centre. From the information gathered during the interviews, the teachers indicated that their role changes when they accompany their students for such Programmes. For example, the roles they play could be those of facilitators, learners, participants, guides, observers, and communicators in the lesson. Some of the teachers even claimed that they felt as if they were one of the students and became like one of them. They believed that they are learners in this environment because the information that was given to the students also underpinned their own learning journey. They learned from the insights and subjects taught during the lessons.

For example, Teacher Number A18 commented that his role changed to one of the participants:

*In the school we are teachers in the sense that we teach them, we clarify their doubts, we have to motivate our students to answer questions, and this is a lot of roles in one go. In the Science Enrichment Programmes, I am more like a facilitator. When someone conducts the lesson I have to see whether pupils understand. Whether they are doing what they are supposed to do and [I am] a participant and learner as well. I get to learn. My role was like one of the participants, sitting with the students, so that I learned what students were learning. At the same time I was participating, facilitating and guiding my students during the lesson.*

Teacher Number A8 described that when she is facilitating and participating with her students, she gets a chance to communicate with them:

*In this enriched environment I got the opportunity to have open communication with the students. I got more time to talk to our students, know them well. In school we don’t have this opportunity because during conducting [of] lessons teachers are so busy in conducting their programmes that they hardly get time to know their students - because I have to finish the syllabus in a given time.*

*In the Science Enrichment Programmes students who feel like they can communicate with their teachers are more likely to ask questions,*
clear their doubts and also seek out the help they need. This ultimately leads to effective learning among both.

According to some of the teachers (viz. Teacher Numbers, A15, A17, L11 and D2), being facilitated, guided and helped during the Science Enrichment Programmes made them feel like they were students:

See what the students need, assisting them and also acting like a facilitator. When I accompany students I am like a student I learn from the instructor. (Teacher Number 17).

By changing this role between being a teacher and participating in the Science Enrichment Programmes with the students, teachers say that they become co-participants in the learning process.

Teachers and students become co-participants in learning skills; for example, they both became familiar with the procedures of microscope viewing. They begin to understand that it is important to know the magnification power used in the observation of different specimens. They come to know that bacteria can be identified based on their shape, arrangement, and the results of biochemical identification tests. In addition, they became familiar with new information such as: each bacterium does not have a nucleus; the DNA flows freely in the cytoplasm of the bacterium. So their role is to learn like students, facilitate, assist and do experiments, go through the procedures and experiments which students are doing. A summative quote from the interview with Teacher Number D20 is given here to conclude this section:

When I accompany students I am like a student I learn from the science educator. They are very knowledgeable. So you get to hear lot of things from them. It is different, their target audience are children so you get this advantage that they give instructions clearly. The pace of instructions is also slow and steady. It is relaxed not so fast.
Pedagogical Content Knowledge

Results revealed that teachers welcomed the opportunity provided them to observe the science educators and to learn from their expertise and different styles of teaching. Teachers mentioned that such visits enabled them to learn new subject knowledge and to acquire new skills and ideas that they could apply in their classroom. Teachers recognised the opportunity that the Science Enrichment Programmes provided to interact with their students and science educators in a non-threatening informal environment. They reported benefiting from this break from the normal teacher-pupil relationship within the usual formal environment.

My results revealed that teachers appreciated how pedagogy and content were put together in the Science Enrichment Programmes. The teachers pointed out that they learned from the science educators how lessons are conducted and delivered to the students.

Shulman (1986) introduced the concept of pedagogical content knowledge (PCK); in brief it is described as “subject matter knowledge for teaching”. According to him, PCK is about a variety of topics, practical forms of presentation, analogies, illustrations, examples, explanations and demonstrations. Shulman (1986) further explained that PCK is also a kind of knowledge which teachers convey to the students in their classroom teaching that includes understanding of particular topics, what makes that topics easy or difficult, and how teachers introduce certain topics, concepts and at the same time clear students’ misconceptions about the subject that they are teaching.
Shulman (1986) explained that PCK is a unique form of knowledge for teaching that makes a content domain understandable for learners. The main aim is how to communicate the science message to the students so that they can understand it easily. According to Bransford, Brown and Cocking (2000), science teachers should not only have good content and subject matter knowledge, but should also possess pedagogical knowledge to teach in a particular discipline. A closer examination of the results reveals that primary school teachers gain a deeper understanding of scientific concepts, knowledge of students as learners, knowledge of instructional strategies, knowledge of assessment strategies, and knowledge of curricular resources.

Most of the teachers in the interviews indicated that the most important things they learned include how to convey a message, how to create a lesson, and how to deliver the lesson. They stated that they benefited from the key questions and key words that were provided in the Science Enrichment Programmes. PCK should, in fact, provide deeper understanding of the important insights for science teachers when they design their programmes for the students (Abell, 2008). As Teacher Number A15 stated:

*I think the challenge is to get the message across, ya, in the sense that students can understand better. Surprisingly, in school, some students even after explaining will not understand fully. For example, forms of adaptations, food webs and food chains may be difficult. A different approach of explaining and showing helped my weaker students. I learned how to be tactful to teach a particular concept to the students.*

Some of the aspects affecting PCK revealed from interviews are as follows:

- Science Enrichment Programmes were well organised
- Science educators are specialised in their field
- Science educators create learning opportunities
Specific methods and skills were used during the Science Enrichment Programmes.

Communication:

(a) New knowledge

(b) Misconceptions.

The Science Enrichment Programmes were well organised

Science Enrichment Programmes provide an organised presentation of material and process (through the use of outlines of the programme, list of steps in the programme, number of experiments, students’ roles hands-on activities, power point slides, and so on.)

Teacher Number D5 described how the Science Enrichment Programmes made her more aware of her own teaching. She elaborated on how her planning and organising changed because of this awareness about learning from these programmes:

*I like the way the lesson was structured; I think the lesson was well planned and quite interesting. The Science Centre is very focused on specific lessons in the schools: it varies according to the different classes and levels. There was a smooth flow from one idea to the next. The words used in the Science Enrichment Programme [were ones] that we could understand, explaining science concepts in everyday language. The science educator was able to read the audience well and pitch up or down appropriately.*

Teacher Number L6 commented that:

*I learned how to link one activity to another. Students have enough space to work on.*

Teacher Number D5 further clarified:

*Science educators were very clear with the content knowledge. Science educators provide an organised presentation of a material sequence of*
lessons, into a coherent course. All activities were conducted in a sequence. Her style of teaching was very natural, that is why she can do a lot.

**Science educators are specialised in their field**

According to the teachers, science educators are specialised people and they give information in depth and in detail. In contrast, teachers in schools are very examination focused. The science educators are very clear in presenting the content, and they know how to handle the students. Knowing subject knowledge very well is a very difficult aspect of science teaching. Also, it is challenging for teachers to learn ways to involve students in conducting hands-on activities, and to know how to help students to understand the content better. In this regard, it is critically important for the teacher to understand the concepts themselves. Teacher Number D13 commented about the science educator in following way:

*I find the difference is the way your science educators conducted the lesson. Science educators have also given very clear instructions. It makes concepts clear. Because your science educators are more knowledgeable than, I would say, our teachers it is something like more specialized. So science educators can provide more insight into the topic for teachers. We don’t know this subject in [as much] depth as science educators. The science educators always take the initiative to update us about information whenever and wherever necessary.*

Teacher Number L10 stated:

*Science educators in the science centre are very professional, because they are able to handle students quite well. They have better knowledge of scientific concepts in areas most of the primary teachers may not have. Students come and learn more about the topic.*

Also, Teacher Number D15 stated that:

*Teachers are responsible for classroom activities that promote the students’ learning process. Teachers need to have a thorough knowledge of the subject matter in order to teach effectively.*
I learn constantly when I bring students for out of school programmes, especially when students come across something they don’t understand. If a question is short and simple, I answer it on the spot, but if it is too long or specialized, I ask them to write it down first so that I can answer it when we get back to school. However, if I myself am not clear, I never hesitate to approach the presenter.

Science educators create learning opportunities

Teachers described in the interviews that one of the benefits which they learned from the Science Enrichment Programmes was how to create opportunities for learning. Science educators helped in creating learning opportunities for students and teachers and enabled them to be familiar with, and make good use of, these opportunities during the lesson. The science educators provided help during each stage of the learning cycle by creating an appropriate learning environment. They provided activities that initiated the learning process by creating an atmosphere and framework conducive to constructively critical review. This meant guiding thinking, challenging students, and ensuring that any conceptual thinking was advanced to meaningful understanding. The process of learning to teach means learning how to systematically organize knowledge so that it can be drawn upon and applied to new situations (Berliner, 2001). Science educators, in the view of the teachers, can do this. Teacher Number D16 stated that the programmes provided her with greater understanding about the teaching process. She was able to transfer the knowledge gained in the Science Enrichment Programme to her own instructions in the class:

Science educators teaching were very interesting. I myself was enjoying her lesson, I learned how to teach. Students were engaged very well with her. They have to answer questions. She is humorous, she is fun, students like her. I have a very good impression of science educators at the Science Centre. Very natural, that is why she can do a lot. Sharing her knowledge. I think it is good for science teachers to attend, teachers enjoy and learn at the same time.

Teacher Number D17 described how the science educator used analogies:
Science educators shared that bricks make a wall, all cells together make tissue. Actually we know that, but the way the presenter used the analogy it became very clear to me as well as to the students.

I learned a lot of things from the lesson, especially how to carry out the lesson. It helps the student’s to internalize what they have learned because they can see for themselves the cells, what they look like rather from the text book pictures which we show them in the class. They remember it better. We have not used the microscopes in the schools for these classes. We found that cells look different here, the specimen is clearer, the image is sharper.

Teacher Number D20 commented that:

Science educators in the Science Centre are well trained. They know how to handle students, how to show things under a microscope. They are trained to engage students. The instructors adjusted the microscope so they know how to show [things]. They let the students go free and explore in the Ecogarden, the hands on part is totally different than school. Science educators are willing and able to become personally involved in the learning process I can improve my teaching looking at the science educators.

Specific methods and skills were used during the Science Enrichment Programmes

Data revealed that the Science Enrichment Programmes helped primary school teachers to develop the knowledge and skills they needed in the classroom. Teachers demonstrated that the Science Enrichment Programmes methods focused more on process skills. This is lacking in schools because, for instance, “we never allowed them to catch things from our eco pond.” (Teacher Number A11).

The three Science Enrichment Programmes used different process skills. Teachers explained that each lesson is different and different lessons have different subject matter to share and different skills to use. Teachers explained that an important skill which they used was observation, but they also had a chance to use their all senses and were able to compare, analyse and classify.
Skills in the Science Enrichment Programmes, and what makes them different from the schools, include the use of practical work, a hands-on approach and a firsthand experience in most of the lessons. For the teachers, however, how the science educators communicate the lessons to the students was an important learned skill. Teacher Number D16 noted that:

_I recall microscope skills. Microscopes are more sophisticated as compared to we have in school. I was not sure myself, when it comes to handling of a microscope. It started with the interaction with the various parts of microscope. Then we were told to use correct procedures to use it. Also the science educator, when she was delivering it, she ensured that they followed the correct steps, ensuring that they start with the lowest magnification first, checking everyone, and making sure that the slides are aligned before she turned on the lights. Using such strict steps I think it helped everyone to learn. After that, when they learned the skill, they were left alone to look at different specimens._

Teacher Number A6 stated:

_I realised that for collecting certain specimens you need certain skills to catch them. For example, catching dragonflies you need a big net and after catching you have to flip the net so that they won’t fly away. I also learned how to transfer a dragonfly into the plastic bags because the science educator told us that all flying animals fly upwards. They saw what a tadpole looks like and in one class they caught a great diving beetle. When they put the specimen under microscope they were so fascinated._

Teacher Number L5 revealed her experience in following way:

_One of the most dramatic skills that I learned during the lesson that I can recall is the shining of the white light through the prism. The experiment clearly shows us that white light is made of seven colours and how it merges into white light again. It was a very fruitful skill for me to learn._

Teacher Number L3 indicated in the interview that skills may be different because the Science Enrichment Programmes use a lot of process skills, whereas in school they were limited “to abilities in the class”:
Observation skills are better and stronger here than learning from a book. Everything we can observe: colours, chemical reactions, the colours of a rainbow. Teachers point [out] that they know the subject matter but they learn about skills and how to use skills in different lessons. I can say [we] learn skills in a practical way. It is important for the teachers to know how to carefully put together science content knowledge and science process skills.

Communication

To teach well, teachers must first understand how students learn. Data revealed that primary school teachers not only learn from the students about how they work in groups but also how the science educators communicate with each group. Teachers demonstrated that they learned how the science educators interact with groups to communicate science concepts and how they use process skills so that students can understand science concepts in an easy way. Most of the time in school, there is so much factual information embedded in a single concept that teachers do not know how to communicate this information effectively. In the Science Enrichment Programmes, they learn how to impart knowledge and ignite students’ curiosity, as Teacher Number D15 stated:

We learned which type of questions we should ask in groups and what works best, so that everyone has a chance to make strong contributions to the discussion. I learned how to ‘spark’ students to understand science concepts.

(a) New knowledge

During the interviews teachers were asked about new knowledge and how it was valuable. Teachers explained that they acquired a lot of new knowledge in the Science Enrichment Programmes. For example, Teacher Number L12 recalled:

I won’t get the experience and exposure which I get here. I think that there is something that I won’t be able to explain to students in school which I didn’t know myself.
When the teacher was asked to elaborate and explain how she got this new knowledge she said:

The science educator asked students to shine light on the prism to observe light. The students saw white light scattering into rainbow colours. After that, the science educator asked students to write the colours in their worksheet. When they wrote the colours the science educator corrected them - these colours should be in a certain sequence. He told them to observe colours again and write them in a correct sequence. They saw the colours and wrote in the correct sequence again. I learned with the students how to arrange the seven colours of a rainbow in the sequence for example red, orange, yellow, green, blue, indigo and purple. After that, some students asked questions of the science educator, why colours spread differently on the wall, and I was impressed by the science educator when he explained about the light colours.

Teacher Number L12 added:

When white light passes through a prism, different colours of light change direction due to different wavelengths and create different angles - that is why rainbows look stretched like a bow. Red light bends at the smallest angle and violet light bends at the largest angle. I and my students didn’t know that before, it was new knowledge for me. Now I know that each colour is arranged according to their wavelengths.

Teacher Number A18 described how she learned new information recently:

I observed pinkish stuff, a sort of cluster of eggs on the rock, so my students asked me what it was. I was not sure, then I asked the science educator. The science educator said, these are the eggs of a giant water snail. I was quite surprised. He said, the eggs themselves are laid one by one and attached to each other in a solid clutch. They are soft and have a milky colour when laid, but harden within hours. Their definitive colour (white, green, and pinkish to bright orange, depending on the species) appears after 1 to 2 days. The egg is such that it can withstand sunlight. And once the snails are hatched they quickly go to the pond, so I learned something new. The eggs should stay moist, but not wet and never be covered with water, as this will drown the baby snails.

Teacher Number A3 mentioned how she learned about the plants:

After getting the specimens from the pond and examining specimens, that part was wonderful. Actually a water banana, I didn’t know it is a
floating or partially submerged plant. I thought it is a floating plant. Then the instructor showed us two types of roots.

Teachers recognised that they not only gained new knowledge but also reinforced existing knowledge, because once a while one does forget certain facts and the Science Enrichment Programmes helped to refresh that knowledge. As Teacher Number D17 stated:

Yes of course, I gained new knowledge in the Science Enrichment Programme, for example the programme on “Diversity of cells” It was new knowledge for me and my students that each bacterium does not have a nucleus. The DNA flows freely in the cytoplasm of the bacterium. This information was actually new to me. New knowledge is like when the science educator mentioned that bacteria can be identified based on their shape, arrangement, and the results of biochemical identification tests.

(b) Misconceptions

Teachers demonstrated that some of their misconceptions were clarified during the programme. They explained that one of the reasons was that in these lessons they were able to get firsthand experience. Teachers mentioned that pictures in the books and real experience are really different: they can use their sensory knowledge to actually see what animals and plants look like, and this learning is for life. Most of the teachers had never come across some of the animals and plants because they did not get the chance to become familiar with these during their training. In the interviews, almost all the teachers mentioned that they saw a dragonfly nymph for the first time and they thought it was a spider.

According to Teacher Number A18, misconceptions were cleared. For example, during the Science Enrichment Programme ‘Aquatic Plants and Animals’:
I like the part, where after catching the dragonfly nymph students asked me, what is this animal? I didn’t know the answer. We thought it was a spider, some said it is cockroach. Even though I teach Science, I didn’t see a dragonfly nymph before. But the instructor cleared up our misconception - it is a dragonfly nymph. It is the young of a dragonfly. A dragonfly has got the largest eyes in the insect kingdom and the nymph breathes through the gills. The instructor pulled out the mouth part of the dragonfly nymph and showed us its mouth. We saw it is like a basket and it can pull it out to catch the prey. Then we compared the dragonfly nymph with an adult dragonfly. It totally looked different than an adult dragonfly. Then we saw the difference between the dragonfly and the damselfly. They totally looked different. She actually showing us things which we did not know e.g. mouth parts, and also showed us the place where the gills are. Definitely, in school we are more textbook based. We show mostly pictures, and if we get videos we show that. We have a small pond in our school, but it is not so diversified. By attending this lesson I learned that we can do more with the pond and I can do more with my students when I go through this lesson.

According to Teacher Number D20:

My background is not science: I am trained in English and Maths. As students ask questions, teachers also ask questions to clear their misconceptions. I have to clear my misconception. I am afraid that I should not give wrong information to my students. By attending this lesson I cleared my doubts.

During classification the science educator talked about algae. So my students were wondering about [it] and they thought it is a plant. Like plants, it makes its own food. Later the science educator introduced the term Protists. So it cleared our misconception about algae, it belongs to the group Protists. It is non-vascular and doesn’t have stem, leaves and roots. It has its own group - it is not a plant.

Misconceptions were cleared, for example, about amoeba and algae, as Teacher Number D7 explained further to viewing these specimens under the microscope:

We thought they are unicellular organisms and they have an irregular shape. When we were shown pond water under the microscope, we saw so many unicellular organisms, they moved on their own. Many were green or had different types of colours.
In summary, the interview responses above revealed that the teachers learned about pedagogy and how lessons were crafted, and that they emerge better equipped with new depths of knowledge. Their responses indicated that they believed that the Science Enrichment Programmes enabled them to teach these lessons more effectively in their classrooms.

It was noted that the teachers’ educational background was important in terms of what they learned during the Science Enrichment Programmes. While some teachers built on to their existing science conceptual frameworks, this was not the case for all the teachers in this study. Conversely, even if some teachers had science knowledge, they may not know how to teach it well. This is because there is a “vast difference between knowing about a topic (i.e. content knowledge) and knowledge about teaching and learning of the topic (i.e. pedagogical content knowledge)” (Bucat, 2005, p.2).

Gains in PCK depend upon the communication, skills and resources made accessible to the teachers, and the connections the teachers are willing to make with a given learning environment, which in this case was the Science Enrichment Programmes. Moreover, teachers need to construct PCK for every lesson that they teach, since each and every lesson is different. This was borne out in the interviews. For example, if a teacher is teaching Aquatic Plants and Animals, it was evident that the communication, skills and resources to teach that subject differed from that gained from the other Science Enrichment Programmes: Light and Diversity of Cells. In fact, Barnett and Hodson (2001) have said that teaching remains a complex activity where teachers continually need to adjust their instructional strategies to ensure student learning. It was important, therefore, to establish how the teachers in the Science Enrichment Programmes
constructed the different knowledge types, including PCK (i.e. Content Knowledge, Classroom Knowledge, and Personal/Professional Knowledge). This further investigation stage was essential to understand more deeply the communications and interactions by the teachers in the Science Enrichment Programmes. The next section describes the observations, which were undertaken towards this aim, as part of this study.

The Main Study - Stage 3: Observations

This section describes the observations that were recorded during the Science Enrichment Programmes. In this study, observations were reserved for the third and final stage of data collection to prevent observer bias (as was established in Chapter 3). Observations followed the analysis of survey and interview data, where the key learning points from the interviews were used to frame the observation guide (see Figure 6). The observation variables paid particular attention to the teachers’ presence and their participation during different stages of the Science Enrichment Programmes. This included information about the physical environment, descriptions of teachers’ behaviour; i.e. their interactions, nonverbal communications, and who speaks to whom and who listens. This data helped to answer the supplementary research questions investigated in the present study:

1. How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

2. How do teachers integrate that learning into their classroom practice?
Observation data were recorded in all of three Science Enrichment Programmes selected for this study (viz. Light, Diversity of cells, & Aquatic Plants and Animals). A total of nine teachers, three from each Science Enrichment Programme, were observed in order to compile the data presented below. Five key points emerged from the observation data, they were:

a. Teachers’ engagement in Science Enrichment Programme

b. Teachers’ active interaction with students

c. Teachers’ communication with science educators

d. Teachers’ recording of the key components of the Science Enrichment Programme

e. Teachers’ responsiveness to students’ expressions

*Teachers’ engagement in Science Enrichment Programme*

In all nine observations, it was noted that the teachers remained in the Science Enrichment Programme environment for the entire duration (i.e. a maximum of two hours). This observation was important, given that the Science Enrichment Programmes were designed and targeted to the learning level of primary school students. Moreover, it is not a requirement for the teacher to accompany students during the entire duration of the programme. In fact, a clear role is not prescribed for teachers accompanying students to the Science Enrichment Programmes.

Furthermore, the teachers continually moved around the Science Enrichment Programme environment among the student groups (SG). Figure 18 shows, for example, a field recording of the teacher’s different positions (T) during the Science Enrichment Programme - Diversity of Cells.
Teachers’ active interaction with students

While the teachers moved around the Science Enrichment Programme environment, they were observed to interact with the students. In some instances, especially during hands-on activities, the teachers were observed to sit among the student groups, just like one of the programme participants. In these instances, the teachers helped to distribute resources within the student groups, for example, passing around worksheets (see worksheets, Appendix XVII, XVIII, and XIX) or other materials. In doing so, the teacher behaved like a group-leader, for example, by demonstrating appropriate ways to examine specimens, use equipment, etc. For example, during the Science Enrichment Programme - Diversity of Cells, one teacher guided the students in adjusting a microscope and encouraged them to identify different specimens as well as to draw their own labelled diagrams.

At other times, the teachers participated with the students in the various hands-on experiments. For example, one teacher in the Science Enrichment Programme – Light
was observed to place a prism and lenses in front of a source of light, while telling students to place different types of lenses against the beam of light. Then, the teacher along with the students drew the light path of the different lenses.

In another example, during the Science Enrichment Programme - Aquatic Plants and Animals, a teacher was seen to join students in catching plants and animals from the Ecogarden ponds. The teacher used the insect-nets, which were provided to the students, to collectively catch dragonflies and other pond-insects. The teacher then shared her specimens with the students and spent time discussing, in the student groups, details about each of the specimens they had caught (Figure 19).

Figure 19: Teacher and students catching insects during the Science Enrichment Programme - Aquatic Plants and Animals, Ecogarden, Science Centre Singapore.

An important observation was that the teachers paid close attention to individual students, while they interacted with different student groups. It was noted, in particular, that the teachers observed the student groups a responsive and respectful manner. They
were observing groups of students while paying close attention to how individual students were working in the groups and how different students assigned different task to each other.

Figure 20: Teacher communicating with the students and asking them questions during the Science Enrichment Programme – Light.

One element that was noted during these interactions was the communication between the teachers and the students – they were often found to ask questions of each other. For example, in the Science Enrichment Programme – Aquatic Plants and Animals, the teacher was asking questions about pond animal (see Figure 20). Teachers actively participated in these communications by asking questions to inform their own understandings about different scientific concepts. For example, in the Science Enrichment Programme – Aquatic Plants and Animals, the teacher and the students were enquiring among themselves, trying to identify a pond insect which they had found in the fibrous roots of a water hyacinth. Teacher together with the students used different cues to guess, in fact suggesting different possibilities for the insect’s identity.
**Teachers’ communication with science educators**

At the beginning of each Science Enrichment Programme the teachers introduced themselves to the Science Educator and, thereafter, participated in the programme while following the instructions provided to the students. The teachers were observed to actively pay attention to the information communicated by the science educator and appeared to be learning scientific content. As stated previously, this learning took place alongside the students, where the teacher was present as one of the student group participants (see Figure 21, for example).

![Figure 21: Learning alongside students: The teacher, standing to the right, joins the student group to listen to information presented by the science educator.](image)

Continuing from the previous example about identifying an unknown pond-insect, the teacher and students collectively put their enquiries to the science educator, who showed them the oar-like legs of the insect, which is one of the characteristics of a *great diving beetle*. Because the teacher expressed willingness to learn other distinguishing characteristics of the great diving beetle, the science educator placed the beetle in a
beaker of water to demonstrate the air bubble it formed in order to breathe under water. The science educator shared further that these beetles can be spotted coming to the surface of the water to replenish their air supply. Like the students, the teacher showed great interest for this information.

When the Science Enrichment Programmes concluded and the students were dismissed, the teachers were observed to approach the science educator to ask questions. These questions were different from the ones they asked when they were sitting among the student groups earlier. While the previous questions focused on scientific content, the questions asked from the science educator after the programme revolved around issues of pedagogy. These included enquires for additional information about specific demonstrations, how to develop and design hands-on experiments, and requests for resources. One teacher in the Science Enrichment Programme – Diversity of Cells, for example, asked questions about using microscopes under appropriate magnification power to view different specimens effectively. The teacher added that in school, they had different microscopes, which did not have the range of magnification demonstrated in the programme.

In another example, after the Science Enrichment Programme – Light, the teacher shared with the science educator that although the hands-on experiments did appear to be simple, they conveyed very important, and often difficult to teach physics concepts. For instance, the teacher noted that the concept: light travels in straight lines, which was commonly taught in the classroom by drawing straight lines on the board. He and his students had experienced this concept profoundly when they experimented with the light box during the Science Enrichment Programme (see Figure 22). In fact, they
teacher shared that he had experimented further with the light box by examining how light travelled through the lenses of his reading glasses. The same teacher was overheard to add that he had learned new methods of incorporating concepts such as “phosfluorescence” into his classroom teaching by using everyday examples.

Figure 22: A light box used by a teacher and students to show the path of light through different lenses in the Science Enrichment Programme - Light.

*Teachers’ recording of the key components of the Science Enrichment Programme*

While it has been mentioned that the teachers were attentive to the information communicated by the science educator, it must be added that they also recorded this information for reference later. During all the observations in the present study, the teachers were noticed to take notes on worksheets that were provided during the Science Enrichment Programmes. For example, in the Science Enrichment Programme – Diversity of Cells, a teacher was observed make detailed notes about the classification of cells and was seen drawing some cells on the worksheet. Another teacher wrote down answers to questions in her worksheets.
Figure 23: A teacher taking photographs of the science educator during the Science Enrichment Programme –Aquatic Plants and Animals.

At other times, the teachers took photographs of the Science Enrichment Programme environment. These photographs featured, generally, students and the science educator in action (see Figure 23). Sometimes, the photographs were of specific demonstrations by the science educator, or students engaging in hands-on experiments. A few were observed taking photographs of drawings made by the science educator on the white board. Some teachers took photographs of the Science Enrichment Programme equipment, such as physics apparatus, microscope slides, and plant and animal specimens. A teacher, in one of the observed the Science Enrichment Programmes - Aquatic Plants and Animals, took photographs of different plants and animals in the Ecogarden; viz. the great diving beetle, the dragonfly and its nymph, and snail eggs. These, she informed the science educator later, she intended to use in her classroom teaching.
Teachers’ responsiveness to students’ expressions

It was mentioned previously that the teachers paid close attention to their students. Careful observation of their behaviour revealed that the teachers were attentive to the feelings expressed by the students as they participated in different Science Enrichment Programme activities. The teachers were noted to look out for students expressing positive emotions such as enjoyment, excitement, enthusiasm, in general any positive attitudes towards learning. For example when the science educator presented new or difficult to understand information, the teachers were noticed to closely observe their students for instances of positive emotions. In such situations the teachers’ facial expressions often mirrored those of the students. During the Science Enrichment Programme -Light, for example, the science educator placed a beaker of water on overhead projector. There was an overall exclamation of appreciation as the students saw a rainbow emerge from the beaker. It was observed that the teacher’s facial expression changed to see her students responding positively to this learning experience.

In another example, students in the Science Enrichment Programme - Diversity of Cells expressed enthusiasm when they were given lab coats to wear. The teacher was noticed to make note of this emotion, which seems to give the students a sense of ‘belonging’ in a conventional laboratory environment. In the same programme, the students were excited to see microscopic organisms in pond water. The teacher, as mentioned previously, was keen thereafter to follow up with the science educator about using microscopes under appropriate magnification power to view different specimens effectively (see the previous subsection titled: Teachers’ interacted differently with the science educator).
In summary, the observations offer evidence that the teachers take up different roles during the Science Enrichment Programmes - when they interact with their students and the science educator. They also appear to behave differently both during and after the Science Enrichment Programmes. Importantly, the observations confirmed that the teachers were, in fact, actively learning in the Science Enrichment Programmes, thus confirming the themes that emerged from the teachers’ interviews earlier.

The observations also revealed insights about crucial components of the Science Enrichment Programmes which enable the teachers to learn, in particular the teachers’ communications between and among the students and science educator. The ways in which the teachers communicated with the science educator and the students, during the different informal learning contexts, offer evidence that the teachers were constructing knowledge actively.

Valuable perspectives were also gained about how the teachers proposed to use their learning to complement their teaching in the classroom. This was evidenced by communications between the teachers and science educator, and the close attention the teachers paid to their students’ learning.

In the following chapter, I discuss the results presented here to draw out their implications and respond in detail to the research questions argued in this study.
Chapter Five

Discussion

Introduction

The present study has investigated teachers’ engagement in the Science Enrichment Programmes conducted at the Science Centre Singapore with attention to the following overarching research question:

Do primary school teachers learn from attending the Science Enrichment Programmes designed for the students at the Science Centre Singapore?

From the pilot survey, it was evident that teachers do learn while attending these programmes. Therefore, the next step in this study was to investigate how these adult learners construct specialised knowledge in informal learning environments that are intended for young learners. To this aim, the second part of the study was designed around the two following supplementary research questions:

1. How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?

2. How do teachers integrate that learning into their classroom practice?

For the purpose of answering the research questions I adopted a modified grounded theory approach. The findings about teachers’ learning were developed through data collected from surveys, interviews and observations.
Based on each of the supplementary research questions mentioned above, three separate investigations were carried out. It was intended that each of these investigations would offer specific perspectives to address the overarching research question.

In order to determine the nature of learning in the Science Enrichment Programmes about specific scientific topics a survey based on quantitative research methodology was administered at the Science Centre Singapore. Results from the survey were used to plan the interview questions that were used subsequently to explore how teachers integrated their learning during the Science Enrichment Programmes into their classroom practice.

The first supplementary research question, ‘How does the communication of science in the classroom enabled teachers’ learning in an informal learning environment provided by the Science Enrichment Programmes?’, was answered with the help of participant observation data that were recorded based on a series of predetermined observational variables (Figure, 6). The key finding from my observations was that the teachers assumed different roles concurrently in the Science Enrichment Programme. From the observations of ways in which they communicated with the science educator and the students, during the different informal learning contexts, it was clear that the teachers actively constructed knowledge. These observations were probed further in the second supplementary research question which explored how teachers integrate this experience into their classroom practice.

The data from the interviews which were facilitated using the Interviews about Instances method, offered the opportunity to examine in detail the elements that were
unique to the teachers’ learning in the Science Enrichment Programme. During the interviews, the teachers described in detail their experiences of the Science Enrichment Programmes, in particular their communications with the science educator and the students. These experiences and reflections on communication of science in the classroom were core to the teachers’ knowledge construction that resulted from this engagement.

In the first part of the following discussion, the researcher will spend time describing in detail the different communications that were observed during the Science Enrichment Programmes. The researcher will draw particular attention to the teachers’ roles in each of these different communications. Thereafter, the researcher discusses active reflection in the light of teachers’ interview responses, while emphasising its role in their knowledge construction. By drawing together the roles of both active communication of science in the classroom and active reflection, the researcher will conclude this discussion chapter by proposing a ‘Teachers’ Learning Model’ for primary science teachers in informal learning environments that are intended for young learners.

**Discussion Part 1: The Teacher’s Role**

The observations conducted during this study were an important element in to witnessing and understanding teachers’ learning in order to answer the first supplementary research question: How does the communication of science in the classroom enable teachers’ learning in the informal learning environment provided by the Science Enrichment Programmes?
In order to understand how the teachers’ actually engaged in the informal learning activities, they were observed during three different Science Enrichment Programmes chosen for the study: viz. Light, Diversity of cells, and Aquatic plants & Animals. The Programmes were chosen from three different locations, namely, the Physics lab, DNA lab, and the Eco-garden. As stated by Cohen, Manion and Morrison, (2005), observation as a strategy presents opportunities “to gather ‘live’ data from ‘live’ situations” (p.305).

As mentioned previously in the literature (see, for example, Zhai & Tan, 2015) teachers’ roles are not fixed. Moreover, these roles depend on certain factors such as the nature of teaching tasks, the types of students and the availability of time and resources in the classroom. While the literature established that teachers’ roles in the classroom had implications for the practice of science as inquiry, these studies did not reveal how teachers learn from the different roles. Observation data in the present study revealed that the teachers adopted the following roles at different times during the Science Enrichment Programmes. The following sections describe the learning that took place by teachers in those different roles.

a. Teacher’s role as an education professional;

b. Teacher’s role as a student; and

c. Teacher’s role as an observer.

The Teacher’s Role as an Education Professional

One of the important roles that teachers assumed during the Science Enrichment Programme was that of an education professional. It was observed that in this role, teachers deepened their professional knowledge by communicating directly with the science educator. It was observed that teachers communicated directly with the science educator mainly at the end of the Science Enrichment Programme, during which they
assumed the role of an education professional and shared experiences on an equal level. Since there was no hierarchy involved, peer learning occurred between the teacher and the science educator. These communications primarily took the form of:

- Feedback about the Science Enrichment Programme; and
- Information about the availability of resources and materials.

**Feedback about the Science Enrichment Programme**

At the end of each Science Enrichment Programme, the science educator gave a feedback form to the teacher to fill in their comments (See Appendix XXIII). This feedback form was not anonymous. As a professional, the teacher provided feedback through this form and returned it to the science educator with comments. Therefore, the researcher was able to trace their individual responses during the subsequent interviews.

**Information about the availability of resources and materials**

It was observed that teachers communicated with the science educator to find out more about the availability of teaching resources. For example, they asked for copies of the slides that were prepared for the Science Enrichment Programme for teaching purposes. Many teachers also asked for answer sheets, power point presentations, reading materials, worksheets, lesson plans and extra copies of identification booklets. These booklets were given to the class in order to help identify plants and animals and match their specimens. These requests were most apparent in the *Aquatic Plants & Animals* Science Enrichment Programmes. Some of the teachers also asked whether the Science Centre could help their school to build a pond, so that their students could continue to learn from similar experiences. To this end, findings of this
study support the work of Sneider (2011), who explained that knowledgeable and skilful teachers have tremendous power to get students interested in science.

The two features mentioned above allowed the teacher to be involved in the Science Enrichment Programmes at a professional level to interact with the science educator. The teacher’s role as a professional/peer learner with the science educator, in particular the communication between the teacher and the science educator, was an important component of the Science Enrichment Programme. For the purpose of consolidating the findings from this research study (as will be discussed later) the researcher has identified communications by the teacher as a peer learner with the science educator as “Dimension One”, and will use the following Figure 24 to illustrate “Dimension One” communications arising from the discussion above.

![Dimension One](image)

**Figure 24: Representation of communication between teacher and the science educator**

**Teacher’s Role as a Student**

A second finding from my results was that the teachers learned from the science educator just like one of the students in the Science Enrichment Programmes. The researcher observed that when the teachers, along with their students, arrived at the respective labs, the science educator took the charge of the whole class. The science educator decided on seating arrangements, content for the lesson, and hands on activities for the programme. In this environment, the teachers became part of the class and followed the same instructions which were provided to the students. During the programme, the teachers constructed information directly from the science educator and
learned from the science educator, just like the students. At the same time however, the teachers facilitated and guided their students during the programme. Three essential features of the Science Enrichment Programmes enabled teachers to communicate as co-learners with their students. These opportunities are listed as follows.

- Co-learning with students;
- Participation in inquiry-based learning; and
- Learning in non-threatening environments.

**Co-learning with students**

As co-learners, the teachers engaged with their students in learning experiences that were offered during the programmes. By this, the researcher means that the teachers interacted with their students in an equal power relationship without the authoritative hierarchy that usually prevails in their classrooms. The teachers and the students were the main participants in the learning process, and learned at their own level. As a co-learner, the teacher also participated with the students in various interactions, experiments and inquiry based learning. At times, the teacher might act like an advanced learner among the group, but still maintained the co-learner status among the students. For example, the teacher learned how to encourage students in an independent, educational environment in which teachers freely raised questions and doubts. In schools, teachers lack the opportunity to learn together with the students. Thus the environment of the programme provided an unusual experience for the teachers.

**Participating in inquiry-based learning**

The teacher’s role as a student gave them an opportunity to conduct the same kind of scientific inquiry that was expected of their students. The Science Enrichment
Programmes enabled teachers to perform experiments and hands on activities with their students. The inquiry-based nature of the programme means that most importance was given to process skills. During the programme, the teachers did not wait for the science educator to provide an answer. Instead, the teachers, as co-learners with the students, were actively involved in seeking answers to a problem. Thus, the teacher’s role as a student helped the development of their own understanding of science. This aspect gave the teacher an opportunity to think independently; for example, to identify and classify the different plants and animals from the pond. It was observed that the teachers analysed their observations with students, differentiated a variety of pond plants and animals and drew conclusions. Most importantly, in inquiry learning, the teachers were responsible for processing the information order to reach their own answers, thoughts and conclusions.

**Learning in non-threatening environments**

A critical finding that emerged from this study results was that programmes provide opportunities for teachers to learn in a non-threatening environment. The main reason for the learning environment being non-threatening for teachers is that the Science Enrichment Programmes are not designed and conducted for them. Therefore, teachers were able to learn according to their own needs. Results revealed that in these environments, teachers were not judged and evaluated by what they were learning and how they were learning. Teachers therefore felt comfortable and confident to learn, and understand new concepts. These findings confirm the statement made by McDonald (1988), that one of the most important aspects of a positive environment is that it must be non-threatening. This feature created opportunities for the teacher to communicate with the students, increased trust between students and the teacher, and facilitated
teacher learning. As stated in literature previously (see, for example, Jung & Tonso, 2006; Holliday et al., 2014), informal learning environments such as museums and science centres create safe and non-threatening environments for teachers to learn. In doing so, these environments increase teachers’ confidence to teach science through student-centred, active inquiry. Therefore, the teacher’s role as a student was an important component of the Science Enrichment Programmes. The researcher has called this Dimension Two, as illustrated in Figure 25.

![Diagram](image)

**Figure 25:** Representation of communication between teacher as student and the science educator

**The Teacher’s Role as an Observer**

The final finding that emerged from the observations was that teachers assumed the role of an observer in the Science Enrichment Programme. In this role, the teachers were seen to be observing their students in groups. The teacher became more aware of student’s individual interests, and their learning preferences. Most importantly, the teacher observed actual student learning. The teacher also observed and recognised the students as individuals, because of the communication platform provided by the programmes. Thus, the teachers had the opportunity to observe students from different perspectives, especially how they interacted actively during learning. Three intrinsic features of the Science Enrichment Programmes enabled teachers to participate as an observer with their students. These opportunities are listed and are listed below:

- Observing individual students during the Science Enrichment Programme;
- Observing and experiencing group dynamics among students; and
• Observing students reactions during the Science Enrichment Programme.

Observing individual students during the Science Enrichment Programme

In these programmes, teachers were seated among their students and were able to observe them as learning took place. In schools, teachers do not have this opportunity. Moreover, as teachers in schools are primarily involved in conducting lessons, they do not have the opportunities in the classroom to observe how students are actively engaged in the learning processes. One of the reasons for this is the teachers’ preoccupation with completion of the given syllabus. Another reason is that teachers have limited time due to the timetable-based curriculum in schools.

As observed, teachers sought to understand students as individuals – each with their own unique viewpoint. The results indicated that the teachers’ learning about their students depended on how much time the teachers spent observing their students and what they observed.

An important finding in this regard was that the researcher heard the questions students raised in a group. The teacher stated that they learned about the types of questions students asked each other during the programme. It should be emphasized that such opportunities do not present themselves in conventional teacher training courses and teacher professional development programmes, as students are not present in those settings.

The findings provided evidence that the students in this environment learn to generate questions themselves rather than answer only the teachers’ questions. The results illustrated that asking questions and communicating with the teacher is effective in
maintaining the students ‘engagement. To this end, findings of this study support the work of Blossom (2004) that people learn by asking questions. When students raise questions, everyone learns, including teachers. The teacher has an opportunity to observe things from the students’ perspective – a very important aspect of being a teacher. Observing students asking good questions also improves the teacher’s understanding about how students think. In some cases, students asked questions that the teachers had never thought of before.

**Observing and experiencing group dynamics among students**

Teachers also observed their students working in teams, and were able to observe the dynamics within the groups of students, which helped to build an atmosphere that supported learning. Group dynamics refers to a system of behaviours and psychological processes that occur within a social group and, in this particular case, learning was facilitated by those interactions. Although the group consisted of students with diverse backgrounds and experiences, the teacher was able to see how connections were formed between them. This confirms the view of Forsyth (2010), that in group dynamics, people are connected to one another and these connections result in emotional bonds.

Thus, the teacher’s role provided them with an opportunity to observe how students bond and build positive relationships with each other. Moreover, in a dynamic group learning environment, every person learns from each other. The atmosphere in student groups, as the teachers observed, was such that everyone in the group could express their opinion about the lesson; they could ask questions. Everyone supported and helped one another as a team. Unfortunately, professional development programmes and other
teacher training programmes do not offer opportunities in which students are present, so that teachers can observe how students learn through these interactions.

*Observing students reactions during the Science Enrichment Programme*

Teachers themselves connected with their students to form positive relationships, because teachers were able to view their students as active learners and were able to identify their student’s roles in relation to other learners. Teachers could observe and even contribute to social interactions. The most common positive attitudes and emotions observed by teachers towards the students were enjoyment, fun, excitement, enthusiasm, and a positive attitude towards learning new facts and concepts.

The teachers reported that they observed these reactions by looking at the students. These positive relationships equipped teachers to understand students’ specific needs, listen to the student’s comments, and observe how these relationships contribute to learning. In these environments, teachers’ foster healthy relationships with their students.

The teacher’s role as an observer is an important component of the Science Enrichment Programmes. For the purpose of consolidating the findings from this research study, the researcher identify communications made by the teacher as an observer of the students as “Dimension Three” (Figure 26).

![Dimension Three](image)

Figure 26: Representation of communication between teacher and the students
From the above discussion, the three roles of teachers learning co-exist during the Science Enrichment Programmes. The integration of these roles, named Dimensions One, Two and Three, provides a unique learning environment for the teachers. Based on the discussion above, the researcher proposes a “Three-Dimensional Communication Model” illustrating the relationship between teacher, student and science educator. The researcher has called it the “Active Learning Environment”. A graphic illustration of the teachers’ “Three Dimensional Active Learning Environment” is shown in Figure 27.

Figure 27: The Three Dimensions of Teachers’ Active Communication in the Science Enrichment Programmes.

It is apparent that this Active Learning Environment is one in which communication takes place between the teacher and their students, the teacher and science educator, and the science educator and students. In the active learning environment, the teacher is able to learn from different roles which are not accessible in other professional courses and teacher-training programmes.
The teachers also demonstrated that reflecting on what they had experienced in the Active Learning Environment helped them to capture the holistic interaction of facts and information obtained by communicating with students and science educators. Although the teacher absorbs facts and information in the Active Learning Environment, it is only through reflection that teachers are able to transform this into useful knowledge. In the following section I will discuss teachers’ reflective learning.

**Discussion Part 2: Teachers Constructing Knowledge**

The researcher has established in the preceding section of this discussion that teachers in the present study assumed different roles in the Active Learning Environment. In this section, the researcher will establish, with reference to the data collected from the interviews, that the knowledge the teachers’ constructed was a result of independent reflections of those active learning roles.

Specifically, interviews were important in this study to understand the kind of knowledge teachers acquire. This knowledge encompassed skills, verbal and non verbal behaviours, and feelings from the active experience. The interview about instances technique (see Osborne & Gilbert, 1980; White & Gunstone, 1992) was used in this study to help in accepting the nature of teachers’ understanding, and their active learning experience. This technique offered an opportunity to probe teachers to describe a complete picture of how they construct knowledge from the different roles they acquire.

For further investigation, each teacher was presented with a matrix (Appendix IX) at the end of the interview to ascertain which type of knowledge the teachers’ acquired during the Science Enrichment Programmes. This matrix is on a five point scale based on
Barnet and Hodson (2001) model, called pedagogical context knowledge. According to them, the ideal teacher uses four kinds of knowledge:

1. Academic and research knowledge
2. Pedagogical content knowledge
3. Professional knowledge
4. Classroom knowledge.

Results from the Matrix revealed that more than ninety percent of teachers acquire all four types of knowledge during the Science Enrichment Programmes.

Essentially, reflective learning is the teachers’ own knowledge landscape, constructed with regard to their own personal knowledge. The researcher draws upon the seminal work by Dewey (1933), who developed the concept of reflective practice and reflection through experiential learning theories. Since then, the role of reflection in teachers’ learning has become more important including the concept of reflective practice in informal learning environments. More than half a century later, researchers, for example Reid (1993), concluded that “reflection is a process of reviewing an experience of practice in order to describe, analyse, evaluate and so inform learning about practice” (p.305). This means that teachers will reflect about active learning experiences in order to equip them for subsequent classroom teaching. It was revealed in this study that teachers were reflecting on their active learning experiences, the communication with their students and the science educator, the hand-on activities, and other learning experiences during the Science Enrichment Programmes. This helped them to develop their own personal knowledge base. They revealed in the interviews that they recalled, subsequently, the features of different components that made elements of the Science
Enrichment Programmes successful, how different techniques and strategies were used to facilitate the teaching process, and how the science educators played on students’ emotions to make the Science Enrichment Programmes interesting and engaging. Their interview responses revealed that by reflecting on the communication made during the Science Enrichment Programmes they constructed new knowledge which potentially influenced their classroom teaching. This observation is consistent with findings by Race (2002), who states that:

The act of reflecting is one which causes us to make sense of what we’ve learned, why we learned it, and how that particular increment of learning took place. Moreover, reflection is about linking one increment of learning to the wider perspective of learning towards seeing the bigger picture. (p.1)

The researcher will spend time in the following section to describe in detail how teachers reflected about their active learning and how they constructed knowledge. In order to streamline this discussion here, the researcher has divided the teachers’ reflections into three categories. Each of the different categories of reflection, essentially, mirrors the active roles they assumed previously. The purpose of this division will be made clear at the end of the following section.

a. Reflection of Dimension One: Teacher’s role as an education professional;
b. Reflection of Dimension Two: Teacher’s role as a student; and
c. Reflection of Dimension Three: Teacher’s role as an observer.

**Reflection of Dimension One: Teacher’s Role as an Education Professional**

The teachers’ interviews responses indicated that they constructed professional knowledge during the Science Enrichment Programme. This knowledge was a consequence of reflection upon their communications with the science educator. Based
on what the teachers said, the professional knowledge they constructed could be subdivided into two areas:

- Teaching methods and skills; and
- Emotions involved in understanding science concepts.

**Teaching methods and skills**

The teachers explained during the interviews that they learned about appropriate methods from the science educator in teaching science, and the skills for the topic they teach in their schools. According to the teachers, knowledge about the topic is only essential when it is paired to a proper set of teaching skills. For example, at the Science Enrichment Programme - Diversity of Cells, teachers explained that they developed the skill of using a microscope because they do not have such high tech equipment in their school. The teachers’ revealed that science educators are knowledgeable, specialized in teaching science topics, and imparted knowledge through storytelling and informal discussions, for example, during the Science Enrichment Programme - Diversity of Cells, the science educator explained a murder mystery story and involved both the teachers and students in using different investigation techniques to solve the murder mystery. Some of the teachers said that they were impressed with the mystery story and that the way it was conducted was something that encapsulated the entire lesson for students.

Other activities focused on helping teachers to improve their understanding of science concepts; for example, the ability to explain the reasons behind using different types of lenses in the light programme. Finally, activities place considerable emphasis on improving teachers' understanding of how students learn by focusing on, for example,
common student preconceptions, misconceptions, and solution strategies in specific subject domains.

*Emotions involved in understanding science concepts*

As the researcher examined results from the interviews, she found that teachers as professionals learnt from science educators about how to stir up emotions for the students while conducting science programmes. Some of the examples teachers mentioned were that they learned how to bring the *wow factor* into their lessons, build excitement and curiosity, and engage the students to make learning more meaningful. One of the important techniques teachers learned from the science educator was to show demonstrations to motivate and capture the attention of the students. The teachers explained that these demonstrations were mostly used at the beginning of the programme to introduce the lesson. For example, in the Science Enrichment Programme - Light, the science educator used a demonstration to capture the attention of students by placing a beaker of water on an overhead projector and then showing the rainbow effect in the classroom. Some of the teachers shared that they were awed by visual effects of the rainbow which made them curious about the dispersion of light. By being engaged themselves, they were motivated to replicate similar phenomenal demonstrations pertaining to science back in their own schools as they understood the concepts better through these simple demonstrations. According to the teachers, the curiosity and interest that was invoked through visual means motivated them to enrol in activities that engaged them through sensory, intellectual, and emotional means - ultimately creating conditions that led to a better understanding of the science.
Reflection of Dimension Two: Teacher’s Role as a Student

From the teachers’ responses during from the interviews, through surveys and observations, it was evidence that teachers constructed content knowledge as a co-learner with students. The teachers added that they learned the content in depth and were able to understand the concepts through practical experience with the students. The teachers revealed that learning is not just a practice of gathering information but it is very important to learn how to communicate content successfully to students. The researcher will spend time in the following section describing the teachers’ reflection about their role as a student that enabled them to develop content knowledge during the Science Enrichment Programme.

Understanding content knowledge to help clear misconceptions

The teachers reflected that in the students’ role, they were able to understand the content knowledge and at the same time clear any misconceptions they had. They said that there was an opportunity to learn science concepts along with the students that helped them to explain the same concepts to their students at a later stage in a school.

The teachers mentioned in their interviews that the programmes are directly related to the school syllabus, making it easier for them to teach these subjects thereafter in their schools. The results from the interviews revealed that teachers were particularly engaged in the activities because they had the time to investigate the hands-on activities themselves.

When the teachers were engaged in the learning process they started investigating and exploring ‘hidden’ knowledge which they did not know or think about earlier. In this
way, teachers were able to understand the concepts better and teach their students accordingly.

The evidence lends support to the importance of reflection in the learning process in a problem based learning environment and how it helps teachers make meaning and construct understanding of new knowledge. Teachers explained that the Science Enrichment Programmes are conducive to inquiry. That spirit of inquiry in these programmes includes the freedom for teachers and students to learn by process. The hands-on experiments are triggers for an inquiry driven and fun lesson. According to teachers, they found answers for their questions by themselves.

**Reflection of Dimension Three: Teacher’s Role as an Observer**

Based on the interview results, it was revealed that by observing students in the Science Enrichment Programmes, it was an extraordinarily valuable experience for teachers to improve their teaching. The teachers’ all had a common consensus that they learned to look at the lesson from the students’ point of view. The teachers’ mentioned that by observing their students they can focus more on what students’ do, how students work in groups, what the students’ strengths are, how the teachers’ can build upon them, and how they can motivate students when they plan for future lessons.

The results also revealed that teachers’ progression of learning about students from the Science Enrichment Programmes and reflecting back their learning about their students played an important part in their personal development. The teachers revealed that school laboratories and classrooms are not like the Science Centre; schools are not well equipped for teachers to observe their students. Results from the teachers’ interview
also showed that in schools, lessons are mostly conducted in the same classroom and laboratories, within the same four walls, and thus, they do not have opportunities to see students in action and have outside hands-on experiments. The teachers explained in the interviews that the extensive lab set up and real life environments are very important for learning. The Science Centre environment through the Science Enrichment Programmes gave an opportunity for teachers to learn more about their students and learn more about what gets their students interested in the subjects and topics – an element which is lacking in schools. The teachers explained that the school environment is not an authentic environment for them to learn about their students. Teachers revealed that they acquire knowledge about the students by observing their needs and how they can fulfil these needs in schools. The teachers demonstrated that practical knowledge about the students cannot be constructed by reading and theory. The results showed that teachers reflected how students gain self-awareness about their learning, how students understand, how students become interested and therefore, how it plays an important role in developing independent learning for teachers to learn about their students.

The results also revealed that the Science Enrichment Programmes made teachers more reflective about classroom knowledge, giving them the ability to learn about their students and the classroom from a fresh perspective. The results further revealed that the teachers had a deep understanding of the learning process that enabled them to become more reflective and conscious when planning their lessons in the school and in making decisions in the classroom. Observing students’ inputs is a valuable resource in the Science Enrichment Programmes, which can help teachers to reflect on their practice and modify their classroom accordingly. The Science Enrichment Programmes provide
teachers with insights about individual students and how students respond to specific learning activities.

The results showed that teaching and learning environments for teachers in the Science Enrichment Programmes prompted and encouraged group effort and facilitated teachers to observe, monitor and evaluate communication behaviour, explore connections between theory and practice, articulate knowledge and understanding, and apply new knowledge and communication skills in their own learning. Thus, the teachers in the Science Enrichment Programmes had the capacity to observe and learn how to facilitate a diverse range of learning activities for their students. The teachers’ interview responses showed that through observation, teachers learn about their students, and also about the teaching that takes place in a social setting that has its own unique characteristics and opportunities for the teachers to learn.

The teachers explained in their interviews that when they attend professional and teacher training workshops, students are not present and they found that it was not a real classroom teaching environment. However, in most of the professional development programmes, the teacher gets information as an adult whereas in the Science Enrichment Programmes teachers see the information from a student’s level. The professional development programmes are also pitched at a higher level and are conducted only with the teachers. In the Science Enrichment Programmes, it is different as it is for students and it is at their level. In the Science Enrichment Programmes, teachers also have the opportunity to experience the way knowledge is communicated to the students’ level. More differences are outlined in Appendix XIII.
The results are illustrated by an inverted triangle (see Figure 28), which portrays teachers’ reflective learning environment. The teachers’ reflective learning environment is a mirror image of teachers’ three dimensional active learning environment (see Figure 28). Through this reflective environment, learning involves the integration of three unique and very different processes of knowledge. The first is professional knowledge, that is the mirror image of communications between science educator and teacher, the second type of knowledge which teachers construct is the content knowledge which teachers develop from their roles as a student by communicating with students, and the third type of knowledge is classroom knowledge/personal knowledge which teachers gain by observing their students in the real classroom.

Figure 28: Teachers’ ‘Reflective Learning Environment’ comprises integration of three types of knowledge.

All three types of knowledge components from reflective learning overlap and interact with each other. The results further revealed that by integrating three types of
knowledge from the reflective learning environment (bottom triangle) another type of knowledge - Pedagogical Context Knowledge is demonstrated. Pedagogical Context Knowledge is the integration of content knowledge, classroom knowledge professional and personal knowledge and this term was coined by Barnett and Hodson (2001).

According to them:

The sources of this knowledge are both internal and external: internal sources include reflection on personal experiences of teaching, including feelings about the responses of students, parents, other teachers to one’s actions; external sources include subject matter knowledge, governmental regulation, school policies, and the like. Interaction with other teachers at both formal and informal levels is both a source of pedagogical content knowledge and a stimulus for its further development. (p.436)

As discussed earlier in the three dimensional active learning environment, teachers have the advantage to learn from three different roles which are not available in other professional courses and teacher training programmes. From the discussion above, my findings revealed that teachers can learn through ‘Active Learning Environment’ - taking different roles by communicating with science educator and students during the Science Enrichment Programme and later through ‘Reflective learning environment’ – where the teachers reflect back about how they develop knowledge from those communications and apply it in their teaching later in the school. In conformance with my results, Schon (1983) suggests two types of reflection that can be engaged in one of two ways; either by ‘reflecting on action’, after the experience, or by ‘reflecting in action’, during the experience. The latter is a more advanced skill while the former is the process more likely to be used when teaching students during the programme.
Discussion Part 3: Teachers’ Active and Reflective Learning Model

This study argues that the Science Enrichment Programmes enable two distinct learning environments. The first environment, called the “Active Learning Environment”, comprises three Dimensions based on the three roles assumed by teachers. As established, these roles are direct consequences of the communications between the three key players: science educator, teacher and students.

In Dimension One, the teacher and science educator interact with one another. The communication in this Dimension presented the teachers in the role of an education professional, where they deepened their professional knowledge by communicating directly with the science educator and shared experiences as an equal. In Dimension Two, where communications were described between the science educator and students, the teacher assumed the role of a student and learned about the subject, thus increasing their conceptual understandings of scientific content. In this Dimension, the teacher, like the other students, constructed new knowledge and deconstructed misconceptions which they may have previously held. A key element of these communications was the non-threatening environment, which was promoted by the informal learning structure of the Science Enrichment Programmes. Previous studies (see, for example, Griffin 1998; Orion, 1993) have stated that informal learning opportunities can offer teachers personally meaningful learning experiences, which can result in teachers developing confidence in their professional practice (Price & Hein, 1991).

Dimension Three consolidated the communication between the teacher and students, especially in group learning environments. Here, the communication allowed the teacher to observe students’ behaviour, thus essentially casting the teacher in the role of
an observer. Through the teacher’s observations of the students’ interactions with one another during the Science Enrichment Programme, the teacher was informed about group dynamics and different learning behaviours fostered by particular students. In doing so, the teacher received insightful perspectives about the students, which they would not normally have in the classroom.

It is concluded that each of the Three Dimensions is an outcome of the teachers’ communication with the science educator and the students. These Three Dimensions come together and form an ‘Active Learning Environment’ during the Science Enrichment Programmes.

Evidence that the Science Enrichment Programmes enabled a second distinct learning environment became apparent from the teachers’ interview responses. This, which the researcher has named the “Reflective Learning Environment”, was a result of the teachers reflecting about the communications in the three Dimensions mentioned previously. Moreover, it was revealed in the teachers’ interviews that they constructed different types of knowledge as a consequence of those reflections. First, by reflecting upon the communications with the science educator in Dimension One; the teachers believed that they developed greater awareness about pedagogical practices that would help them to communicate scientific information more effectively with their students. These included skills for presenting different scientific topics, and methods of strategically organising activities related to particular topics. An important element of the teachers’ reflections about Dimension One communications was the equal sharing platform between them and the science educator, which enabled peer-learning to take place. This opportunity to communicate on equal status as education professionals, the
teachers pointed out, fostered reflection that led to the construction of a unique knowledge base; i.e. Pedagogical Content Knowledge.

Second, by reflecting upon the communications with the science educator and teachers’ role as students in Dimension Two, the teachers believed that they developed in-depth understanding about the subject that helped to clear their misconceptions. The new knowledge which they constructed helped them to communicate and translate scientific concepts into more meaningful learning experiences. An important element of the teachers’ reflections about Dimension two communications was the non-threatening environment. By this, the researcher means that the informal learning environment enabled the teachers to co-participate freely with their students in the learning process. Moreover, the opportunity to learn alongside with students is not commonplace in conventional teacher education paradigms. The opportunity to communicate as co-learners with their students, the teachers mentioned, fostered reflection that led to the construction of a unique knowledge base; i.e. Content Knowledge. These findings support previous studies; for example, that teachers improve their relationship with students as documented by Jeffery-Clay (1990), which can positively influence subsequent classroom teaching (see, for example, Kisiel, 2005; Price & Hein, 1991).

Third, from Dimension Three, teachers reflected that they observed the complex interactions among students that influenced their learning in the Science Enrichment Programmes. The teachers stated that they developed greater awareness about their students’ behaviour. They believe these insights would help them to communicate scientific information more meaningfully with their students. The teachers described unique opportunities to observe students’ emotions. For example, they saw first-hand
how students become motivated and interested in a particular scientific topic, how they built new connections to understand content, and the ways in which they get engaged with classroom activities. These unique perspectives to observe students actively engaged in learning are completely absent in other conventional learning opportunities that are presented in traditional teacher training programmes. The opportunity to communicate as an observer, the teachers pointed out, fostered reflection that led to the construction of a unique knowledge base; i.e. Classroom Knowledge.

It is evident from these results that the teachers’ learning was influenced by a combination of three types of knowledge in the Reflective Learning Environment: Pedagogical Content Knowledge, Content Knowledge, and Classroom Knowledge. Furthermore, these three types of knowledge overlap and interact with each other and by integrating form Pedagogical Context Knowledge. It is important to note the enabling context played by incidental learning; i.e. “learning outside of formally structured, institutionally sponsored, classroom-based activities” (Marsick & Watkins, 1990, pp.6-7), in the construction of the above knowledge types. These results confirm previous research, such as Price and Hein (1991), which suggested that teachers can learn incidentally from informal learning settings designed for students.

Representation of Pedagogical Context Knowledge in this study is a combination of knowledge which is an outcome of the teachers’ reflections of their communications during the Science Enrichment Programmes, and most importantly their communications which enabled the different roles with the science educator and students in the Active Learning Environment. Furthermore, from the above discussion, this study argues that the two distinct learning environments created by the Science
Enrichment Programmes are fundamental factors for teachers learning. By bringing together the teachers’ learning from both environments, I am able to derive the teachers’ learning model.

The ‘Active Learning Environment’ represented in Figure 29. The triangle at the top depicts the teachers’ different role, by communicating with the science educator and students. On the other hand, in the ‘Reflective Learning Environment’, teachers constructed pedagogical context knowledge from the communication and interaction from the Active Learning Environment. An important feature of this model is that it provides an effective, unique and realistic structure for teachers learning.

Figure 29: Illustrates Three Dimensional Teachers Learning Communication Model in Active and Reflective Learning Environment of the Science Enrichment Programmes.
In the last chapter of the thesis, the researcher presents the implications of the Teachers Active and Reflective Learning Model. The limitations of this study and recommendations for future research are also documented in the concluding chapter.
Chapter Six

Conclusion

Introduction

The overarching research question of this study was:

Do primary school teachers learn from attending the Science Enrichment Programmes designed for the students at the Science Centre Singapore? If so, what is the nature of their learning?

In response to the questions about teachers' learning, the conclusions generated through the analysis of the data from diverse sources offered evidence that primary school teachers do learn during the Science Enrichment Programmes which are conducted for the primary school students in Science Centre Singapore. These programmes provide a new learning experience for the teachers with their students and enable an examination of their own learning by reflecting that learning through various dimensions. Such work is demanding, and is not professional development but ongoing learning.

The study showed that communication of science in the classroom across these dimensions plays a critical role for the primary school teachers in learning from the Science Enrichment Programmes which were essentially designed and conducted for students. In summary, these communications helped the teachers to interact with both science educators and students by assuming different roles during the Science Enrichment Programmes so as to construct facts and information in an active learning environment and later transfer the same facts and information into knowledge by the
teachers through reflection. This investigation indicates that the benefits of communication of science in the classroom practices should not be limited only to traditional professional development of teachers but that modelling communication with students in an informal learning environment is also important.

The findings of this study enabled the creation of an ‘Active and Reflective Teachers Learning Model’ that revealed how primary school teachers learn and construct knowledge from programmes which are designed for students. The model integrates priorities for personal and professional development of these teachers. All these things are happening in an active and reflective environment; the fact is that teachers are learning by taking different roles and by communicating within these roles. The model indicates that teachers consolidate their learning at a deep level through reflective practice. The model can form the basis for describing teachers’ learning in any informal learning programme.

The critical finding of this study is that when teachers learn in a non-threatening environment, where the primary focus is on their students, they construct knowledge which enables reflection and enhances classroom knowledge in a holistic way. This kind of learning is not provided by traditional professional development. These experiences need to be recognised as continuous learning opportunities for teachers. It is also important to recognise the incidental nature of this learning, which is implicit and unplanned.

It is important to recognise that teachers’ learning during the Science Enrichment Programmes was not anticipated by the organisers. One possibility to promote teachers’
learning during the Science Enrichment Programmes would, therefore, seem to be to prepare teachers in advance. By this, the researcher means preparing teachers to anticipate what they might be expected to learn when they accompany their students to the Science Enrichment Programmes. This expectation, however, would destroy the non-threatening environment and incidental nature of learning for the teachers, which the researcher has highlighted as a key element of teachers’ learning during these programmes. Therefore, the researcher believes that for primary school teachers to expect to learn during the Science Enrichment Programmes would destroy the dynamics which have been highlighted as a key element. Following the Science Enrichment Programmes, there should be no expectation that what teachers have learned will be assessed. The Science Enrichment Programmes therefore should not be promoted to schools, teachers or even science centres as professional development programmes.

**Recommendations of the Study**

The following recommendations are made for future studies in communication of science in the classroom of enrichment programmes, for science education, and the uncharted territory that lies between:

**Recommendation 1**

The study was focused mostly on primary school teachers’ learning during three of the Science Enrichment Programmes at the Science Centre Singapore. However, it would be useful to replicate this study with other teachers in other Science Enrichment Programmes, as well. In particular the programmes designed for high school students would be of interest.
**Recommendation 2**

A second recommendation is to initiate discussion groups for primary school teachers to have an opportunity to discuss their learning from the Science Enrichment Programmes. One possibility of this would be to have informal discussion groups online, where teachers share their comments through discussion forums or in person at the Science Centre or in teachers’ own schools. There is evidence in the literature to support peer collaboration for professional learning of teachers. Peer learning is an educational process where peers interact with other peers interested in the same topic. In peer learning, teachers learn with and from each other. However, they all share the general aim of focusing teachers on improving their practice and learning together about how to improve students’ learning.

**Recommendation 3**

In order to obtain a better appreciation of the understandings constructed by the teachers, it is recommended that a follow-up study should examine the teachers’ subsequent classroom practices, possibly, by way of reflective journals and written self-reports.

**Recommendation 4**

The teachers would benefit from backup resources for lessons in their classroom. For example, important notes, lesson plans, answers for the worksheets, science kits, videos and pictures from the Science Enrichment Programmes would assist in consolidating the learning experience. It would be important to demonstrate how the
Science Enrichment Programmes could be linked to school programmes, and how teachers could implement them more effectively in their schools.

**Recommendation 5**

Last, the recommendation is that further research should be conducted to show how inter-communication among students, leads to the construction of knowledge for both students and teachers. This would be an exploration into students’ communications during the Science Enrichment Programmes. How do they communicate with each other in understanding concepts during the programmes? How they come to understand concepts through attitudes and emotions, and how do those communication practices facilitate their learning?

**Limitations of the study**

**Limitation 1**

The main focus of my study was only on primary school teachers’ learning during three of the Science Enrichment Programmes at the Science Centre Singapore. It did not compare other Science Enrichment Programmes offered at the Science Centre Singapore, or elsewhere, for primary schools to see whether teachers learn in those programmes which promote similar aims.

**Limitation 2**

This study limited its investigations to the personal understandings teachers constructed during the Science Enrichment Programmes. It did not, purposefully, explore the teachers’ classroom practice that they conducted post-workshop participation.
This research indicates that the Science Enrichment Programmes are a useful platform for primary school teachers to learn science with their students. In these programmes they communicate, bond and learn science with them by looking through different lenses at their students’ learning. This study has shown that the science centre practices inspired the teachers and enabled deeper understandings about the science and their students which the teachers believed informed and improved their classroom practice. It will be critical for the Science Centre Singapore and for the Ministry of Education Singapore to decide how best to use these findings without destroying all the benefits of incidental learning.
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Appendix I: Science Centre Singapore

Science Centre Singapore

The Science Centre Singapore opened in 1977, promoting informal learning of science through interactive exhibits, galleries, talks, demonstrations, film shows, publications, science camps and science competitions (Bhathal, 1982). According to Poon (2014) the science centre is a professional body that plays a significant role in supporting the teaching of science in schools in Singapore. According to Teo (2000) minister of education and second minister for defence on the occasion of the re-launch of science centre Singapore and world premiere of the dinosaurs alive! exhibition stated:

The Singapore Science Centre has grown in strength over the years, and its range of science exhibitions, educational, and promotional programmes continues to be popular with our schools. It continues to play an important role in the promotion of science and technology and their relevance to everyday life to our school students and to the wider public. With its exhibits, laboratories and enrichment programmes, the Science Centre plays a vital role in complementing the formal science education that takes place in our schools. (p.1)

Science Centre Singapore has positioned itself as a place where science befriends and transforms the minds of millions. It strives to be a centre of excellence for informal education. The Science Centre Singapore is like a “resource hub", in other words it is like a basket full of unique programmes and rich materials (Figure A1). Materials in the basket can be exhibitions, exhibits, science shows, demonstrations, talks, worksheets, guided tours, science club activities which cater their services for all male or female, teacher or student, individual or group. Visitors, especially students and teachers, who visit Science Centre Singapore, choose materials from this basket according to their own needs and interests. After they have made their choice, the experience it also depends on how they interact with these materials. If all these materials are presented and used in a proper way, then learning is more fruitful. Rennie and Williams (2002)
have made the point that people do not absorb scientific knowledge directly, unchanged, from any source but visitors restructure knowledge to suit their own needs.

According to St. John & Perry (1993):

Science museums provide an array of resources that help people not only to learn science but also, more broadly, to develop long-term relationships with content, phenomena, and issues of science. (p.59)

Figure A1: Visual representation of Science Centre Singapore as a “resource hub”.

This resource hub that Science Centre offers serves as a platform that offers various programmes to 3 key types of patrons – Visitors, Teachers and Students. Table A1 shows the different types of programmes that cater to each type of patron, highlighting Science Centre Singapore as a platform for informal education.
Table A1: What Science Centre Singapore offer to Visitors, Teachers and Students

<table>
<thead>
<tr>
<th>Three key types of patrons of Science Centre</th>
<th>Visitors</th>
<th>Teachers</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Families, tourist, teachers and students</td>
<td>Pre-school, primary and secondary school teachers</td>
<td>Pre-school, primary and secondary school students</td>
<td></td>
</tr>
<tr>
<td>• Exhibitions</td>
<td>• Workshops</td>
<td>• Enrichment Programmes</td>
<td></td>
</tr>
<tr>
<td>• Science demonstrations</td>
<td>• Seminars</td>
<td>• Science competitions</td>
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<tr>
<td>• Science shows</td>
<td>• Conferences</td>
<td>• Science clubs activities</td>
<td></td>
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<tr>
<td>• Science talks</td>
<td>• Special previews for the science exhibitions</td>
<td>• Volunteer programme</td>
<td></td>
</tr>
<tr>
<td>• Family day</td>
<td>• Teacher attachments</td>
<td>• Promotional activities</td>
<td></td>
</tr>
<tr>
<td>• Science camps</td>
<td>• Teacher learning journeys</td>
<td>• Outreach activities</td>
<td></td>
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<tr>
<td>• Science in a café</td>
<td>• Special orientation for pre-service teachers</td>
<td>in a school</td>
<td></td>
</tr>
<tr>
<td>• Volunteer programme</td>
<td></td>
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</tr>
</tbody>
</table>

**Programmes for teachers**

Dairianathan and Lim (2014) stated that teachers are a valuable bridge between schools and the education department. The Science Centre advises on needs for different students and also initiates development of resources that benefit students and teachers. According to Dairianathan and Lim (2014, p.268) teachers’ professional development is addressed through:

- **In-service teacher workshops**: The main focus is on science content and how teachers can make science teaching interesting and facilitate understanding of concepts are also conducted. In 2012, a total of 3,293 in-service teachers attended teachers’ workshops, learning journeys, teachers’ previews and feedback sessions as well as symposium and seminars organised by the science centre.

- **Orientation for pre-service teachers**: Before graduating from the National Institute of Education, all pre-service teachers attend a compulsory orientation at the science centre to familiarise themselves with resources useful to them and to
understand the partnership role of the science centre . Close to 1,000 pre-service teachers undergo this orientation each year.

- **Teacher attachments at Science centre Singapore**: Take in teachers on 2-year or shorter-term attachment so that they will return to formal teaching with new methods or innovative approaches adopted from an informal education experience.

*Programmes for Students*

“A range of science enrichment programmes, volunteer programmes, annual events and competitions, outreach programmes and school-based activities and resources have been popular with teachers for their students for many years’. Be it a workshop in one of our specialised teaching labs, a lecture demo or an engaging problem-based exploration of an exhibition gallery, all programs aim to complement the school science curriculum with hands-on and inspiring learning experiences” (Science centre website, 2015).
Appendix II: Information Sheet for Research Participants

I am studying for a Doctor of Philosophy (PhD) degree at the Australian National University (ANU). In fulfilment of the doctoral programme, I am working on a research project entitled **Primary school teachers learning in Enrichment Programmes conducted at the Science Centre Singapore**.

I wish to invite you to take part in my research study. The period of participation takes place between September 2011-January 2012. I will be focusing on the following three programmes and I would like to survey teachers who attend one or more of the following programmes.

- **Diversity of cells:** DNA Lab
- **Aquatic plants and animals:** Eco Garden
- **Light:** Physics Lab

The aim of my study is to explore and gain insights into primary teachers learning in science Enrichment Programmes which are tailored for students at the Science Centre Singapore. Through my investigations I hope to understand how teachers apply this learning in their classroom teaching.

The survey will be conducted at Science Centre, after the teachers accompanying their students have participated in the Enrichment Programme. It should take no more than 10 minutes to complete the survey.

The information collected from all research participants will remain confidential. Research participants will remain anonymous or be referred to by pseudonyms. Personal information will be de-identified and coded as far as and as early as possible. This information will be stored in a secure site at Science Centre for a period of 2 years from the completion of the research, after which time all data will be destroyed. All records containing personal information will remain confidential and no information which could lead to identification of any individual will be released. The data will be protected against all loss or theft and unauthorised access, disclosure, copying, use and modification. Security measures taken will involve restricted access and password protection.

Your participation is fully voluntary. You will be required to complete a questionnaire about your experiences of the Enrichment Programmes. If you wish you may choose not to participate in the survey or withdraw at any time should you feel uncomfortable? There will be no adverse impact if you do not participate or wish to withdraw from this study. If you agree to take part in this study, you are kindly requested to sign and complete an informed consent form before you begin your participation.

Your participation is deeply appreciated. If you have any questions, please feel free to contact me at [s.sharma@science.edu.sg](mailto:s.sharma@science.edu.sg) or Tel: +65 98422071.

Yours faithfully,
Savita Sharma

**Principal Supervisor**: Professor Susan Stocklmayer (Director, Australian National Centre for the Public Awareness on Science, ANU)
Tel: +61 2 61258157  E-mail: Sue.Stocklmayer@anu.edu.au

**Human Research Ethics Committee**
Tel: +61 2 61253427  E-mail: Human.Ethics.Officer@anu.edu.au
Appendix III: Enrichment Programme Pilot Survey

Dear Teacher,

The Science Centre Singapore would like to get your feedback on the Science Enrichment programmes that it conducts regularly for the schools. Your assistance in completing this survey form will be greatly appreciated.

Level: Primary ___

Name of the Enrichment Programme:

Number of years of teaching experience:
- < 1 year □
- 1-2 years □
- 3-5 years □
- 5-10 years □
- >10 years □

Please tick (√) the relevant option

1. Is this your first visit (as a teacher) to the Science Centre with a class?
   Yes □  No □

2. If your answer to the above is ‘No’, how many times over the past 5 years have you brought your students to the Science Centre Singapore?
   1-2 □  3-4 □  More than that □

3. You bring students to learn topics related to:
   - Physics □
   - Chemistry □
   - Biology □
   - Kitchen Science □
   - DNA learning lab □
   - Robotics or Movie studio □
   - Others (please specify)___________________________

4. Which activity do you feel is more beneficial for students?
   - Lab lessons □
   - Lecture demonstration □

5. Why did you bring your students to Science Centre Singapore? (You may tick more than one option)
   a. Related or connected to school syllabus □
   b. To complement classroom science lesson □
   c. To enthuse them about science and technology □
d. Easy to understand

e. To give students hands on experience

f. To make learning interesting

g. To get new ideas for teaching

h. Because of lack of such facilities in the school

i. Others (please specify)_______________________________

6. Who booked for you and your class to attend this Enrichment Program?
   Yourself   [ ]   Your HOD   [ ]   Administrator   [ ]

7. Is the topic of the Enrichment Programme linked to your current classroom topic?
   Yes   [ ]   No   [ ]

8. Was any information provided in the programme new to you?
   Yes   [ ]   No   [ ]   Some of it   [ ]

9. If any of the information was new, will you use it in your classroom teaching?
   Yes   [ ]   No   [ ]   May be   [ ]

10. Can you briefly explain how you will use it?

_________________________________________________________________

11. What is your highest educational qualification?
    a. High School Diploma or (polytechnic)   [ ]
    b. B.A./B.Sc.   [ ]
    c. Masters   [ ]
    d. Others______________________________

12. What subject area (s) have you majored in?
    a. Physics
    b. Chemistry
    c. Biology
    d. Mathematics
    e. English
    f. Others (please specify)______________________________

Thank you😊
Appendix IV: Informed Consent Survey Form

Principle Investigator: Savita Sharma
Institution: Australian National University
Research Title: Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers
Research Method: Survey
Place: Science Centre Singapore

I have been given and read the Information Sheet describing the study and the nature of the study, including surveys. I understand and voluntarily accept the invitation to participate in the above study. I understand the purpose and process of the research project and my involvement in it.

I also understand that

- I can at any time prior to publication withdraw from participation without penalty, prejudice, negative consequences, repercussion, or disadvantage and demand that my personal data/information be permanently deleted from the database.
- the researcher will use my personal data/information solely for this study.
- the researcher will render my personal data/information anonymous and protect the privacy and confidentiality of my personal data/information.
- while information gained during the study may be published, I will not be identified and my personal data/information will remain confidential.
- the ethical aspects of the project have been approved by the ethics committee of The Australian National University

If I have any questions about the research at any point in time, I will contact Savita Sharma at +65 98422071 or email her at s_sharma@science.edu.sg

Name of participant: ............................................................

Signature: ........................................... Date:
.................................
Appendix V: Science Enrichment Programme Questionnaire Final Survey

Dear Teacher,
I would like to invite you to participate in a research study that I’m undertaking as a student of the Doctor of Philosophy programme with the Australian National University

Name: _______________________
Date: _______________________
School: _______________________

Level: Primary:

Primary 4  □  Primary 5  □  Primary 6  □

Name of the programme:

Aquatic plants and animals □
Diversity of cells □
Light □

Place where it is conducted:

DNA lab □
Eco Garden □
Physics lab □

Please tick (√) the relevant option

1. Number of years of teaching experience
   < 1 year □
   1-2 years □
   3-4 years □
   5-10 years □
   >10 years

2. What subject area(s) have you majored in? (Select more than one, if applicable)
   Biology □
   Business organisation □
   Chemistry □
   Economics □
   Engineering □
   English □
   Mathematics □
   Physics □
   Others (please specify)________________
3. What subject(s) do you currently teach in your school? (Select more than one, if applicable)

- English [ ]
- Math [ ]
- Science [ ]
- Social Studies [ ]
- Others (please specify) ____________________________

4. How many times over the past 5 years have you accompanied your students to the Science Centre?
   - 1-2 times [ ]
   - 3-5 times [ ]
   - more than five times [ ]

5. If you answer is more than two times what was the main purpose of your visit? Please specify: ___________

6. Why did you accompany your students to Science Centre today? (You may tick more than one option)
   - Lesson related or connected to school syllabus [ ]
   - To complement classroom science lesson [ ]
   - To enthuse them about science and technology [ ]
   - To give students hands on experience [ ]
   - To make learning interesting [ ]
   - Easy to understand [ ]
   - To get new ideas for teaching [ ]

7. Was the information provided in the programme new to you?
   - Yes [ ]
   - No [ ]
   - Some of it [ ]

8. If any of the information was new, will you use it in your classroom teaching?
   - Yes [ ]
   - No [ ]
   - May be [ ]

9. If No, why would you not use it in the classroom?
   ________________________________

10. In which way will you use the information in your school?
    - As an follow up activity [ ]
As an enrichment
To introduce a lesson
To recollect what has been learnt
Others (please explain how you would use it)_________________________

11. Can you write down few things that are not available in the school or different than school.
   Teaching resources
   Method of teaching
   Learning facilities
   Others (please explain/describe)_____________________ 

12. Do you agree that teachers and students are co-participants in the learning process?
   Yes ☐   No ☐   Some of it ☐

13. Why do you feel that way (as stated in your answer above)?
   _____________________________________________________________________
   _____________________________________________________________________

Would you mind if I contact you again for an interview
   Yes ☐   No ☐

If yes your;
   Phone: _________________________ Email: __________________________
Thank you very much for your time filing the survey form
Appendix VI: Informed Consent Interview Form

Principle Investigator: Savita Sharma

Institution: Australian National University

Research Title: Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers

Research Method: Interview

Place: Participating Primary School Teachers in Singapore

I have been given and read the Information Sheet describing the study and the nature of the study, including interviews. I understand and voluntarily accept the invitation to participate in the above study. I understand the purpose and process of the research project and my involvement in it.

I also understand that

- I can at any time prior to publication withdraw from participation without penalty, prejudice, negative consequences, repercussion, or disadvantage and demand that my personal data/information be permanently deleted from the database.
- the researcher will use my personal data/information solely for this study.
- the researcher will render my personal data/information anonymous and protect the privacy and confidentiality of my personal data/information.
- while information gained during the study may be published, I will not be identified and my personal data/information will remain confidential.
- the ethical aspects of the project have been approved by the ethics committee of The Australian National University

If I have any questions about the research at any point in time, I will contact Savita Sharma at 98422071 or email her at s_sharma@science.edu.sg

Name of participant: .................................................................

Signature: ........................................... Date: ...........................................

.................................
Appendix VII: Email to Teachers

Dear teacher,

I am Savita Sharma working as a Senior Science educator at the Science Centre Singapore for the past 19 years. I am studying for a Doctor of Philosophy (PhD) degree at the Australian National University (ANU). In fulfilment of the doctoral programme, I am working on a research project entitled Primary school teachers learning in Enrichment Programmes conducted at the Science Centre Singapore.

I am focusing on the following three programmes and I would like to interview teachers who have attended one or more of the following programmes.

- Diversity of cells: DNA Lab
- Aquatic plants and animals: Eco Garden
- Light: Physics Lab

The aim of my study is to explore and gain insights into primary teachers learning in Science Enrichment Programmes which are tailored for students at the Science Centre Singapore. Through my investigations, I hope to understand how teachers apply this learning in their classroom teaching.

I would really appreciate it if I could meet you for an interview regarding the enrichment programmes. It should take not more than 30 minutes to interview. The information collected from all research participants will remain confidential. Do let me know when you are free, and I will come down to your school to meet you. Your participation is deeply appreciated. If you have any questions, please feel free to contact me at s_sharma@science.edu.sg or Tel: +65 98422071.

Yours faithfully,
Savita Sharma
Appendix VIII: Interview Guide

Principle Investigator: Savita Sharma

Research Title: Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers. Do they learn and how that learning is developed. What elements of the presentation assist teacher learning.

Target Interviewees: Participating Primary School Teachers in Singapore

1. As a teacher what comes to your mind when you visit Science Centre with your students.

2. I would like to specifically ask you what your experiences were when you attended the Enrichment Programme at the Science Centre with your students. Would you like to share what you experience?

3. Now let me show you some pictures of the Enrichment Programme, which you attended last year. Looking at these pictures, do you recall which part of the Enrichment programme you really gained a lot from in terms of what you felt and what you believed as a teacher during your visit?

4. Ok, you choose this picture showing _____ activity in the programme. That is very interesting. I would like to hear more, can you tell me more about the _____ activity?

5. What types of experiences have you and the students gained from these activities at the Science Centre?

6. If you say hands-on and first-hand experiences. How could this help your students?

7. Besides these experiences, what other things did your students learn?

8. How have these experiences benefited you as a teacher?

9. Do you think the learning experiences in the Science Centre are different from the experiences you offer in your school?

10. If yes, can you highlight some?

11. How would you describe your feelings about those experiences?

12. Why do you think those experiences are different from the learning experience at the Science Centre?
13. Next Question. Do you believe that the teaching methods that were used in the Science Centre were different to the teaching methods you use in your school?

14. How do you believe the teaching methods at the Science Centre will be helpful to your teaching in school?

15. Do you remember any other specific activity that was done that day?

16. What is it about this activity/these activities that made you remember them so well?

17. That is interesting. Do you think there was a difference in your role with the students at the Enrichment Programme compared to your usual role with them in school?

18. How would you feel about using the role you adopted in the Enrichment Programme to change your present teaching in school?

19. By looking at this matrix, would you like to identify what types of knowledge, you believe that you got from the Enrichment Programme?

20. This new knowledge you have gained, can you explain how it is valuable to you?

21. Is it possible for you to apply the knowledge you developed in the Enrichment Programme back in your school?

22. How do you see yourself using information from the Enrichment Program in your classroom teaching?

23. Can you give me some examples?

24. Did you notice any instances in the Enrichment Programme that might have cleared any misconceptions about science which perhaps your colleagues at school or your students may have had?

25. When you attend other workshops and professional development courses, do you find there is a difference, compared to the Enrichment Programme you attended at the Science Centre?

26. Do you believe that the Enrichment Programme that you attended should be considered as a part of your personal learning journey as a teachers?

27. How would you design the Enrichment Programme to be part of the learning journey of teachers? Is there anything you would like to do differently?
### Appendix IX: Matrix

<table>
<thead>
<tr>
<th>Learning type</th>
<th>Some examples of this type of learning</th>
<th>Learning examples stated by teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning type I (Academic and research knowledge)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about science concepts and facts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about historic information about scientific discoveries and scientists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about how students learn science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much of this type of knowledge was evident in the Enrichment Programme</td>
<td>1 A little</td>
<td>2</td>
</tr>
<tr>
<td><strong>Learning type II (Pedagogical content knowledge)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about how to teach science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about introducing difficult science topics to students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about motivating students to learn science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much of this type of knowledge was evident in the Enrichment Programme</td>
<td>1 A little</td>
<td>2</td>
</tr>
<tr>
<td><strong>Learning type III (Professional knowledge)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about school science curriculum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about the mission and goals of the Science Centre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about resources available to teach science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much of this type of knowledge was evident in the Enrichment Programme</td>
<td>1 A little</td>
<td>2</td>
</tr>
<tr>
<td><strong>Learning type IV (Classroom knowledge)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about your students’ learning preferences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about your students’ abilities and their prior science knowledge <em>(Hint: Misconceptions will be here)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt about your students’ attitudes to science learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much of this type of knowledge was evident in the Enrichment Programme</td>
<td>1 A little</td>
<td>2</td>
</tr>
</tbody>
</table>
Appendix X: Picture used for interview (Aquatic plants and animals)
Combine the food chains into a food web.
Appendix XI: Picture used for interview (Diversity of Cells)

Concept Recognition/Concept Application

Microbe Murder Mystery

*Objective lens: during the practical, use the lens indicated in bold letters
- Low power objective lens: 4x (red) and 10x (yellow)
- High power objective lens: 40x (blue) and 100x (black)
Appendix XII: Picture used for interview (Light)

Concept Recognition/Concept Application

a) Shine 3 beams of light through lens 1.

b) Draw the path of light as it travels out of the lens

---

c) Draw the path of light through the following lens shapes:

---

d) Complete the following sentence

Light travels in straight lines but we can change its _____________ using a lens.
The ___________ the curve of the lens the more light changes its ___________.
b) Which letter does the light beam reflect to?

A  B  C  D

(circle the correct letter)
## Appendix XIII: Professional Programmes VS Enrichment Programmes

<table>
<thead>
<tr>
<th>Teacher Professional development Programmes</th>
<th>Enrichment Programmes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Conducted mostly for teachers</td>
<td>Conducted for students</td>
</tr>
<tr>
<td><strong>2.</strong> With teachers</td>
<td>With students</td>
</tr>
<tr>
<td><strong>3.</strong> Types of professional development</td>
<td>Types of Enrichment Programmes</td>
</tr>
<tr>
<td>Education conferences</td>
<td>Hands on Lecture demonstrations</td>
</tr>
<tr>
<td>Seminars</td>
<td></td>
</tr>
<tr>
<td>Workshops</td>
<td></td>
</tr>
<tr>
<td>Mentoring and peer observation</td>
<td></td>
</tr>
<tr>
<td>Participation in a network of teachers</td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td></td>
</tr>
<tr>
<td>Observation: teachers observing other teachers</td>
<td></td>
</tr>
<tr>
<td>Online courses.</td>
<td></td>
</tr>
<tr>
<td><strong>4.</strong> Conducted in any convenient place/ labs/Lecture Hall/Auditoriums/</td>
<td>Conducted in specialised labs DNA labs Ecogarden Physics lab</td>
</tr>
<tr>
<td><strong>5.</strong> Organised by</td>
<td>Organised by</td>
</tr>
<tr>
<td>Formal/ Informal</td>
<td>Informal</td>
</tr>
<tr>
<td>For example</td>
<td>Science Centre</td>
</tr>
<tr>
<td>Ministry of education</td>
<td></td>
</tr>
<tr>
<td>NIE (National Institute of Education)</td>
<td></td>
</tr>
<tr>
<td>Schools</td>
<td></td>
</tr>
<tr>
<td>Informal learning institutions</td>
<td></td>
</tr>
<tr>
<td>- Zoo</td>
<td></td>
</tr>
<tr>
<td>- Botanical gardens</td>
<td></td>
</tr>
<tr>
<td>- Bird park</td>
<td></td>
</tr>
<tr>
<td>Science museums</td>
<td></td>
</tr>
<tr>
<td>Science centres</td>
<td></td>
</tr>
<tr>
<td>Private Vendors</td>
<td></td>
</tr>
<tr>
<td><strong>6.</strong> Mostly Theory / Practical based</td>
<td>Mostly Practical based/Hands-on</td>
</tr>
<tr>
<td>Teachers learn teaching skills in theory</td>
<td>Teachers learn teaching skills practically</td>
</tr>
<tr>
<td><strong>7.</strong> Related to the methods of teaching ,</td>
<td>Related to school syllabus topics</td>
</tr>
<tr>
<td>skills and strategies</td>
<td>Specific topics</td>
</tr>
<tr>
<td>Common topics</td>
<td></td>
</tr>
<tr>
<td><strong>8.</strong> Pitched at high level (adult level)</td>
<td>Pitched at students level</td>
</tr>
<tr>
<td><strong>9.</strong> No practical setting of teachers</td>
<td>Teachers can observe students and how they learn</td>
</tr>
<tr>
<td>learning in classroom</td>
<td></td>
</tr>
</tbody>
</table>


Appendix XIV: Interview Transcript (Aquatic Plants and Animals)

Principle Investigator: Savita Sharma

Research Title: Science Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers

Do they learn and how that learning is developed. What elements of the presentation assist teacher learning

Target Interviewees: Participating Primary School Teachers in Singapore.

Researcher: Good morning.
Teacher: Good morning Mrs Sharma

Researcher: Thanks for your time as I know teachers are always busy. I would like to ask few questions, and answer as you feel.
Teacher: Yes of course, No Problem.

Researcher: As a teacher what comes to your mind when you visit Science Centre with your students.
Teacher: I always think hmmm.... Science Centre is great and fun place to bring my students. When I think about Science Centre I always think of hands-on activities, interesting exhibits, and the kind of interaction students can perform in the Science Centre. Oh yes! Especially experiential learning making meaning from direct experience.

Researcher: Would you give me an example?
Teacher: Yes, hmm.... by experiential learning using senses.

Researcher: Would you explain that further?
Teacher: I believe in learning outside the classroom. When I bring students they get chance to see things, they can touch, smell, observe and feel. I would like to specifically ask you what your experiences were when you attended the Enrichment Programme at the Science Centre with your students. Would you like to share what you experience? I experienced interactive learning first-hand. We were provided with chances to see and touch various types of specimens (both plants and animals), which we don’t get to do back in schools. I believe that we (student and teachers) learn better from doing hands-on and observing real specimens. Provide teachers with the knowledge and skills to look at diversity of plants and animals.

Researcher: Now let me show you some pictures of the Enrichment Programme, which you attended last year. Looking at these pictures, do you recall which part of the Enrichment programme you really gained a lot from
in terms of what you felt and what you believed as a teacher during your visit?

Teacher: I remember learning an immense amount of information when I attended a class on aquatic plants and animals. I have taught this topic in school but unlike the Science Centre, we do not have a variety of plants and animals to show and talk about to kids. At the Science Centre, my students had a lot of fun learning to catch plants and animal specimens and viewing them under the microscope. There’s only so much that a student can learn from a textbook. Students need new motivations each time. The Science Centre provided a conducive and fun learning environment whereby, students were thought to use different equipment (nets, microscopes etc.). Actually I like all the activities but I like the part where I and my students got chance to collect plants and animals from the pond. I never had such experience before.

Researcher: Ok, you choose this picture showing students catching animals at the Eco garden during the programme. That is very interesting.

Teacher: I choose this activity (catching animals from the pond)

Researcher: What types of experiences have you and the students gained from these activities at the Science Centre?

Teacher: Students were blessed to enjoy a fun learning environment and hone their understanding on various aquatic plants and animals. I believe that since the students were able to participate in the learning of this topic, they will definitely be able to retain information readily and in their long-term memory. Even I learnt new techniques, such as how to catch a dragonfly/damselfly. Before I attended this course, my understanding of this topic was textbook based. The Science Centre taught me more by allowing me to experience the observation of plant and animal specimens first-hand.

Researcher: If you say hands-on and first-hand experiences. How could this help your students?

Teacher: Touch is a fundamental learning point for children. Sensory experiences are very important for long-term learning as they probe further thinking (open-ended questions). Psychological studies have shown that observational skills and hands-on learning are both very important for moulding good educational experiences. Let me give you an example of my personal experience. When I did my diploma and degree, I learnt various modules, had a whole stack of textbooks and notes to memorize. The bulk of what I remember now are all my hands-on experiences (research, dissection etc.). Through hands-on and first-hand experiences, students are able to relate to the topic better.
Researchers: Besides these experiences, what other things did your students learn?

Teacher: Beside hands-on skills, students strengthen their observational and thinking skills. For instance, many of the students did not know that pond skater is an insect. So when they caught a pond skater, they were asked to count the number of legs and from then on decided if it is an insect... This allowed students to put their thinking caps on which at the end of the day allowed them to better classify the information they obtained. By the end of the class, they were better able to group aquatic plants and animals to their respective categories (locations, diet etc...). Students most importantly, also learnt how to work well in groups. They bonded with their classmates and were able to adapt to a different learning environment.

Researchers: How have these experiences benefited you as a teacher?

Teacher: I feel engaged when my students are engaged. When teachers know their subject well they feel confident. This will make it easier for me to further summarise on the topic back in school. Even my understanding of the topic was further strengthened, and at least I now know that I will be imparting knowledge to a higher degree as compared to the generalized knowledge I have learnt from the textbook. I also got a chance to see my students working in a group and how to get them excited, interested and engaged.

Researchers: Do you think the learning experiences in the Science Centre are different from the experiences you offer in your school?

Teacher: Yes definitely!

Researchers: If yes, can you highlight some?

Teacher: First-hand observation of live plant and animal specimens. The Science Centre has a diverse variety of these groups of living things. In our school pond, we only have a limited type of specimens. These specimens are bought from the shop and they do not survive for long in our school ponds. But over at the Science Centre, there is a greater diversity of aquatic life. We also do not have many microscopes in our school, as it is a primary school learning environment. Over here at the Science Centre, kids were taught how to operate and view specimens under a microscope. It was an all-round experience. They were allowed not only to carry out hands-on but also analyse the plants and animals they have obtained. Students came across specimens they have never seen before and were taught their correct names. We even looked at one drop of pond water contain so many organisms.
Researcher: How would you describe your feelings about those experiences?
Teacher: Very educational and enriching experiences.

Researcher: Why do you think those experiences are different from the learning experience at the Science Centre?
Teacher: The Science Centre is more equipped with materials that are important in the learning of this topic. They have many ponds, varieties of plant and animal live, microscopes. Basically everything needed for a conducive learning environment. Most importantly, the educators are specialised in the topics they are teaching and communicate well so they are able to impart more to the kids. I learnt how to teach this topic, even I teach this topic I came across first time with diversity plants and animals.

In Science Centre I act like a facilitator, rather than a teacher. So as I go around facilitating students, I can observe them how they learn. That is a difference

Researcher: Next Question. Do you believe that the teaching methods that were used in the Science Centre were different to the teaching methods you use in your school?
Teacher: Yes to a certain extent. Back in school, we teach everything by the book. Even though back in school, we do promote inquisitive learning, I believe that the Science Centre is more experienced in doing that. The educators taught the students the right way to view the specimens, to analyse and how to classify them. I also learnt the technique to look at some animals hidden in water hyacinth plant roots. Instructor teaching is very interesting. I myself was enjoying her lesson; I learned how to teach this lesson from her because they are specialized to teach this lesson. Children were engaged very well with her. They have to answer questions. She is humorous and students like her. I have very good impression of educators at the Science Centre

Researcher: How do you believe the teaching methods at the Science Centre will be helpful to your teaching in school?
Teacher: I am definitely going to bring back some of the fun methods of teaching in school. I do know my students well but sometimes you do not pay enough attention to what engages your students. When I attended this class, I was also better able to understand and relate to my students. So now, I will try and make all my science lessons more interactive and fun for my students.
Researcher: Do you remember any other specific activity that was done that day?

Teacher: I though using the microscopes to view specimens was very interesting. We were able to look at the specimens in a greater detail.

Researcher: What is it about this activity/these activities that made you remember them so well?

Teacher: The hairy body and compound eyes of the dragonfly. Hahaha. Students were also allowed to view microscopic organisms under the microscope.

Researcher: That is interesting. Do you think there was a difference in your role with the students at the Enrichment Programme compared to your usual role with them in school?

Teacher: As I mentioned earlier on, this enrichment programme allow me to bond with my students. I was also allowed to participate in the catching of specimens and identifying specimens with them. I was able to observe my students. My role was just taking part in the activities which students were doing and got chance to understand concepts by sensory experience.

Researcher: How would you feel about using the role you adopted in the Enrichment Programme to change your present teaching in school?

Teacher: I will definitely feel optimistic. Not only did the students learn so did I.

Researcher: By looking at this matrix, would you like to identify what types of knowledge, you believe that you got from the Enrichment Programme?

Teacher: I would say everything from academic to classroom knowledge.

Researcher: This new knowledge you have gained, can you explain how it is valuable to you?

Teacher: Academic and research knowledge: Hone my understanding of various scientific concepts, discoveries, how students learnt science. When I go back to school, I can teach my students with more confidence and impart a greater deal of process skills. Science educators were very clear with the content knowledge. Science educators provide an organised presentation of a material sequence of lessons, into a coherent course. All activities were conducted in a sequence. Her style of teaching was very natural, that is why she can do a lot.

Pedagogical content knowledge: Very importantly, I understood my students better. I now know how to better
motivate them. Students always to be taught in a fun way

to keep them motivated and engaged.

Professional knowledge: I learnt about the various
resources available to the Science Centre so I can now
sign up for more scientific enrichment classes in relation
to the topics we cover back in school.

Classroom knowledge: I now better understand my
students’ attitude towards fun science learning. In the
Enrichment Programmes students who feel like they can
communicate with their teachers are more likely to ask
questions, clear their doubts and also seek out the help
they need. This ultimately leads to effective learning
among both. I learned how to be tactful to teach a
particular concept to the students.

Researcher: Is it possible for you to apply the knowledge you
developed in the Enrichment Programme back in your
school?

Teacher: Yes definitely. I saw a wow factor, they were engaged and
interested, and as a teacher I learned that these factors
are good in teaching science and how to make students
interested.

Researcher: How do you see yourself using information from the
Enrichment Program in your classroom teaching?
Can you give me some examples?

Teacher: I will try and make scientific learning more fun and
interactive for the kids. Try to bring in more live
specimens (for instance, to revise whatever they have
learnt at the Science Centre). I will make PowerPoint of
pictures and revise in the class. I have ask each group of
students to share their experience in the class.

Researcher: Did you notice any instances in the Enrichment
Programme that might have cleared any
misconceptions about science, which perhaps your
colleagues at school or your students may have had?

Teacher: I have never seen a dragonfly nymph before in my life.
When I attended this course, I was given a chance to view
it and also learn more information about it. For example
looked at mouth parts, compound eyes and also looked at
the gills. When I caught it, I thought it is a spider. by
looking at it and counting the legs and body parts then
science educator told us it is a dragonfly nymph. Me and
my students were also able to see difference between
dragonfly nymph and damselfly nymph. This experience is
amazing. Before this course, I also did not know about
the correct methods of catching dragonflies but now I can
proudly say that I can catch a dragonfly.
Researcher: When you attend other workshops and professional development courses, do you find there is a difference, compared to the Enrichment Programme you attended at the Science Centre?

Teacher: Of course, there is a difference. Professional courses mostly are organised for adults and pitched at higher level. Not so exciting students are missing. Mostly are not based on specific topic which we teach in the school. Here I can understand content on students level. How they ask questions. When we go for other professional courses students are missing. It is more theory based. Here everything is practical. You can see how students get interested, wow factors etc. Science Centre has its own unique way to engaging students with more hands-on and enquiry based learning. I believe that it should be considered as a learning journey of a teacher.

Researcher: How would you design the Enrichment Programme to be part of the learning journey of teachers? Is there anything you would like to do differently?

Teacher: I think it is very important the way teachers learn with the students, it was learning on the job and with the students it is fun and interesting. I will try to plan conduct more hands on lessons and try to use examples which trainer used during the lesson.

Researcher: Thank you so much.
Appendix XV: Interview Transcript (Diversity of cells)

**Principle Investigator:** Savita Sharma

**Research Title:** Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers

Do they learn and how that learning is developed.

What elements of the presentation assist teacher learning

**Target Interviewees:** Participating Primary School Teachers in Singapore.

**Researcher:**

Good afternoon.

Teacher: 

Good afternoon. Mrs Sharma

**Researcher:**

Thanks for your time as I know teachers are always busy. I would like to ask few questions, and answer as you feel.

Teacher: 

Yes of course, No Problem.

**Researcher:**

As I spoke to you on the phone, my name is Savita Sharma. Thanks for your time as I know teachers are always busy I would like to ask a few questions about the lesson which you attended in science centre. Do you recall the name of the programme which you attended last month?

Teacher: 

Yes, I came to attend one of the DNA Lesson “Diversity of Cells “with my pupils.

**Researcher:**

Do you remember “Diversity of Cells” enrichment programme. I would like to specifically ask you what your experiences were when you attended the Enrichment Programme at the Science Centre with your students. Would you like to share what you experience?

Teacher: 

Yes, of course.

**Researcher:**

Why do you remember this so well?

Teacher: 

I remember practical interaction with the students and how science educator organise delivering of the programme. My experience about the environment was totally different. Everything was focused on the topic. For example Lab set up, posters on the walls about the plant cell and animal cells and microscopes my personal experience with looking at different specimens through microscopes.

**Researcher:**

Now let me show you some pictures of the Enrichment Programme, which you attended last year. Looking at these pictures, do you recall which part of the Enrichment Programme you really gained a lot from.
in terms of what you felt and what you believed as a teacher during your visit?

Teacher: I choose these two pictures, Microbe murder mystery and microscope part. Ahh. hmmm... First thing I remember my experiences with students was to see them getting excited wearing the lab coats, with them I was also excited. Student felt very important. Primary school students are visual learners, sometimes very difficult to explain some science concepts.

Researcher: What is the special part in the Enrichment Programme that you enjoyed most during your visit?

Teacher: I like the way workshop was structured. We were given information first and then asked to solve the mystery. I personally enjoyed. hmmm... I really like the part “Solve the mystery game”. Actually I liked the whole lesson. It was really eye opening experience for me.

Researcher: Could you tell me more about this mystery game? How it was done?

Teacher: Solve the mystery game? Oh... well it was a detective game where we had to find out who had murdered this victim, whose body was found in the pool. It felt very nice, just like the movies. I was very interested and it really it kept me and the students engaged. All of us were interested and curious about finding results of the mystery.

Researcher: Oh! Wow that’s interesting, so did you manage to solve the mystery?

Teacher: Yes, of course. We were able to solve the mystery. It was very engaging indeed. The students were given three samples, and they had to match it with the DNA found on the victim’s body.

Researcher: So did you remember what samples were given?

Teacher: Let me try to recall... Hmm... ya I do. The samples were in the swimming pool, pond x and pond y, if I am not wrong.

Researcher: Did you recall which slides you prepared?

Teacher: If I am not mistaken, Hydrilla, human cheek cells and yeast

Researcher: Besides that was there anything that you found particularly interesting?

Teacher: Oh ... Yes now I remember cheek cells, I think it is a good activity to do something out of their own body. And students get to see that cells belong to their own body. That make me and my students excited. They have not seen cheek cells before.
Researcher: Do you think all these experiences can be provided to them in the school?  
Teacher: Of course not, Science Centre is very focused on specific lessons. Master copy of cells and cheek cells which we don’t have in the school. We don’t have type of microscope which you have. Students were familiarized with the procedures of microscope viewing, Know the magnification power used in the observation of specimens. I recall we learned also the wet mount preparation of slides and same technique I can follow in my class. We don’t have authentic slides and specimens. They were also given master copy of cells which we don’t have.

Researcher: Do you think teaching method and skills used in Science Centre were different than School?  
Teacher: Yes, In Science Centre Methods and skills become different. Lessons are more on inquiry based as I gave you example of mystery game earlier and also lessons are more on hands on activities, firsthand experience of living things makes methods and skills different than school.

Researcher: Can I ask if the programme had an effect on the way you teach science?  
Teacher: Yes of course, I gained new knowledge  
Researcher: Can you give an example?  
Teacher: New knowledge is like when the instructor mentioned that bacteria can be identified based on their shape, arrangement and the results of biochemical identification tests. Each bacterium does not have a nucleus. The DNA flows freely in the cytoplasm of the bacterium. This information was actually a bit new to me.

Researcher: Would you like to add on anything else besides new knowledge?  
Teacher: Some misconceptions were cleared.

Researcher: Can you give an example of that as well?  
Teacher: For one particular organism, the presenter talked about Euglena. So my students were wondering it was plant cell or animal cell. Later the science educator introduced the term Protists. So it cleared our misconception about Euglena that it belongs to group protests’. My other misconception that was cleared by the presenter was that Bacteria live in colonies; they survive independently and do not form tissues.

Researcher: Do you think the teaching methods and skills are different or same like schools?
In schools most of the time it is theoretical. Students learn from textbooks or use internet, over here it is different as they get to see real things, they can see cells themselves, use microscope themselves. This adds on to the interest that they have in science.

Do you think the workshop was relevant to your needs?

Yes of course, even the environment has an effect on teaching science. I learned lot of things on how to present activities one by one, and even lab coats and the lab setting gave students feeling they are not just students but (can be) scientists.

I remember it was two types of cells. For animal cells, I tried to make a slide of our own cheek cells. We were told to scrape our skin from our cheeks and spread it on the slide. It was a very good experience - we could see our own body cells, how they look. After that, the students and I saw the difference between plant and animal cells. They really can see differences. For example, for the plant cell they saw chloroplasts, as a teacher I also saw all the differences. For example, animal cells do not have a cell wall whereas plant cells do. We saw [that the] animal cell has an irregular shape while the plant cell has a fixed shape.

Did you take part in completing the worksheet?

I took selective notes on the worksheet because I was myself taking part in the activities and also guiding students for the activities. So I was not a teacher but like a facilitator. In other words I considered myself like a student learner.

What do you mean by learning like a student?

I was following same instructions from the science educator which was given to students. I was also following hands on activities. I was part of the programme like other student.

How do you see yourself using information from the Science Enrichment Programmes in your classroom teaching?

Oh, yah, every time I attend a lesson, I observe and I do learn something new, learn what I should carry on doing in classroom. I also learn to think of alternative ways to present the pedagogy. As a teacher, I not only gain knowledge but it is also a form of reinforcement because sometimes, I might have forgotten certain facts but when I come for the enrichment class, I get refreshed and personally I learn lot of interesting facts like ‘who discovered cells’. These programmes add on knowledge.
to classroom lessons and, in other words, it provides teachers with a new perspective.

Researcher: When you attend other workshops and professional development courses, do you find there is a difference, compared to the Enrichment Programme you attended at the Science Centre?

Teacher: The professional courses are conducted for us and are usually pitched at a much different and higher level. These are usually not so exciting. In Science Centre, it is interesting because it is for students and the language used is also simpler and easier to understand. It is given in very simple to understand means and ways. Science Centre puts in a lot of effort to package the Enrichment Programmes and exhibitions so that everyone can learn from it. Science Centre has ‘wow’ factors using interesting methods to attract the attention of students.

Researcher: Finally, to some up, do you agree that you as a teacher learn along with the students?

Teacher: Yes, I am still learning and by attending this type of lessons gives me confidence to teach science. I think it is very important the way teachers learn with the students, it was learning on the job and with the students it is fun and interesting.

Researcher: Thank you very much.
Appendix XVI: Interview Transcript (Light)

**Principle Investigator:** Savita Sharma

**Research Title:** Science Enrichment programmes designed for primary school students in Science Centre Singapore contribute to the learning of primary school teachers

Do they learn and how that learning is developed. What elements of the presentation assist teacher learning

**Target Interviewees:** Participating Primary School Teachers in Singapore.

**Researcher:** Good afternoon.

**Teacher:** Good afternoon Mrs Sharma.

**Researcher:** Thanks for your time as I know teachers are always busy. I would like to ask few questions, and answer as you feel.

**Teacher:** Yes of course, no problem, you can ask the questions.

**Researcher:** As a teacher what comes to your mind when you visit Science Centre with your students.

**Teacher:** I always think hmmm...to me it is hands-on activities, interesting exhibits, and interactions students and teachers can have. I find Science Centre a fun and interesting place to come. Basically, the idea was to get us to know more about science concepts. All the interesting things we could not show in the class.

**Researcher:** I would like to specifically ask you what your experiences were when you attended the Science Enrichment Programme at the Science Centre with your students. Would you like to share what you experience?

**Teacher:** My experience was very good, as in schools it is focused on theory and have limited experiments for the light topic. In science centre there are equipment and relevant resources to conduct experiments on light. What student sees in text books they don’t grasp so well as compared to see actual things. When they see actual things they internalise they learn.

**Researcher:** Now let me show you some pictures of the Science Enrichment Programme, which you attended this year. Looking at these pictures, do you recall which part of the Science Enrichment programme you really gained a lot from in terms of what you felt and what you believed as a teacher during your visit?
Teacher: I choose these two pictures (showing prism and lenses). I really liked the activities with prism and with lenses.

Researcher: Ok, you choose these two picture showing students prism and lenses. That is very interesting.

Teacher: What I could remember is the science educator was able to show how the white light is scattered into rainbow colours and back into white light. I also like the activity where we were supposed to shine light through different lenses. It was really an engaging experience. In a book, we see the lines (Light travels in a straight line) which students cannot visualise. However, when they conduct the experiment in science centre, they really understood the concept of light and what those lines meant on the book.

Researcher: What types of experiences have you and the students gained from these activities at the Science Centre?

Teacher: I would say, we gained more visual experiences. Personally I think, the students had learnt much more from visual representations. The pictures they can capture in mind could have long lasting impact on them. Retention of the knowledge will be much longer for adults as well. For example, if you show me word and picture I rather remember the picture.

Going out is really fun to us. Certain experiments cannot be conducted in school. It is great idea to go to the science centre to learn on relevant topics related to syllabus.

Researcher: If you say hands-on and first-hand experiences. How could this help your students?

Teacher: The programme provided unique opportunities for the students to participate in hands-on activities which allow them to understand the concepts in the conducive environment. For example, students were given light box, prisms, and lenses to perform experiments. Students performed activities and record observations. It was very good experience for us too.

The way science educator use resources to teach were very interesting. For example, when science educator switched off all the lights, it was a very distinctive experience. The most important was activities were related to real life examples of refraction. e.g. how the eye and spectacles work.
Researcher: How have these experiences benefited you as a teacher?
Teacher: Of course! I experience the way your science educator conducted the lesson because your science educator is more knowledgeable than I would say our teachers. Science educator provides more insight to the topic. I would not have given this experience anywhere else.

Researcher: Do you think the learning experiences in the Centre are different from the experiences you offer in your school?
Teacher: Yes,

Researcher: Could you highlight some?
Teacher: It is totally different experience in the Science Centre. We are free to explore.

Researcher: Would you explain that further?
Teacher: What I found different from school is that lessons conducted in Science Centre are more towards inquiry approach.

Researcher: Can you explain it further?
Teacher: For example, Students were given instructions before every activity and they were provided with set of equipment. For each activity they have to conduct and figure out the results themselves. For example first activity in the worksheet. They have to shine light at different angles to see where it is reflected, later they were told to measure angle of incident and angle of reflection. By doing that they came to know that both angles are the same.

Researcher: Anything else you would like to add on.
Teacher: We are unable to demonstrate to students certain concepts, we can only explain to them by PowerPoint or by book which they might not understand. Students need real life experiences themselves to understand.

Researcher: Do you think teaching method and skills used in Science Centre were different than School?
Teacher: Yes of course, we do provide hands on experience in the school, however, there are limited resources. For example, we do not have facility of dark room. So, we cannot explain some of the concepts on light. That is why it is easier for us to learn and explain concepts in the Science Centre. There some things which we don’t focus on. For example, added on knowledge and more enrichment. Using hands on experience makes the methods and skills different.
Researcher: How would you describe your feelings about those experiences?
Teacher: My feelings were good because my class was learning and there was wow factor.

Researcher: Why do you think those experiences are different from the learning experience at the Science Centre?
Teacher: Of course different.

Researcher: Next Question. Do you believe that the teaching methods that were used in the Science Centre were different to the teaching methods you use in your school?
Teacher: The way lesson and hands on activities were conducted makes method different. We cannot perform all these experiments which we did in science centre. It is very important for the learner to learn from reality. Now I will go back and reinforce the concepts of light in my teaching.

Researcher: How do you believe the teaching methods at the Science Centre will be helpful to your teaching in school?
Teacher: As I said earlier, in science centre teaching is student oriented and fosters a sense of excitement and motivation for us to learn more.

Researcher: Do you remember any other specific activity that was done that day?
Teacher: I and my students like the activity were science educator shine the light on a beaker of water, which caused the rainbow on the wall. It was new thing which I learnt.

Researcher: What else can you explain?
Teacher: The interesting part was students were asked to write down the colours which were projected on the wall.

Researcher: Anything else?
Teacher: Some students asked questions for example, why colours are like that, and I was impressed by the science educator when he explained about the light colours.
Example explanation I remember; When light passes from one material to another (e.g. from water to air) it refracts, meaning it changes direction/bends. Different colours of light change direction at different angles.
Red light by the smallest angle and violet light by the largest angle.

Researcher: Wow! You remember quite a lot, that’s quite impressive.
Teacher: Lot of things which are set up and dedicated to particular group. Students move on from one activity to another. Students have enough space to work on.

Researcher: What is it about this activity/these activities that made you remember them so well?

Teacher: It is related to our syllabus and I learnt how to explain certain concepts to students.

Researcher: That is interesting. Do you think there was a difference in your role with the students at the Science Enrichment Programme compared to your usual role with them in school?

Teacher: My main role as a teacher in this programme changed. I was acting like a facilitator and at the same time learning from students and science educator.

Omm...I was listening to the science educator and assisting in some of the activities which my students found them difficult. I was also taking pictures of students and set up of experiment. At the same time, I helped students to answer their questions and observed how students worked in a group and learnt from hands on activities.

Researcher: How would you feel about using the role you adopted in the Science Enrichment Programme to change your present teaching in school?

Teacher: By observing Science Enrichment Programme on light, definitely I have gained experience for this topic as my background is not physics.

Researcher: By looking at this matrix, would you like to identify what types of knowledge, you believe that you got from the Science Enrichment Programme?

Teacher: I would say everything from academic to classroom knowledge.

Academic and research knowledge: Hone my understanding of various scientific concepts about light, how students learnt science. I can now teach my students with more confidence and impart a greater deal of process skills.

Pedagogical content knowledge: Very importantly, I understood my students better. Now, I know how to motivate them; I learnt how certain experiments can be done and linked to the daily life examples; How lessons can be taught in a fun way to keep students interested motivated and engaged; I learnt how to present activities in a systematic way

Professional knowledge: I learnt about the various resources available in science centre. I can now sign up
for more scientific enrichment classes in relation to the topics we cover back in school.

Classroom knowledge: I now better understand my students’ attitude towards fun science learning.

**Researcher:** This new knowledge you have gained, can you explain how it is valuable to you?

**Teacher:** The practical part of the science is mostly lacking in schools.

**Researcher:** Is it possible for you to apply the knowledge you developed in the Science Enrichment Programme back in your school?

**Teacher:** Yes, of course.

**Researcher:** How do you see yourself using information from the Science Enrichment Programme in your classroom teaching?

**Teacher:** Definitely. I can improve my teaching through observing programmes and how the science educators teach and interact with the students.

**Researcher:** Can you give me some examples?

**Teacher:** For example, reviewing answers, observations and summarise concepts. How to highlight real life examples of using reflections and refraction e.g. car mirrors, our eye and how spectacles work.

**Researcher:** Did you notice any instances in the Science Enrichment Programme that might have cleared any misconceptions about science which perhaps your colleagues at school or your students may have had?

**Teacher:** There were not any misconceptions to clear but there were new knowledge and new skills to learn. For example, I learn about how to demonstrate rainbow in the class by shining light through beaker of water on an overhead projector.

**Researcher:** When you attend other workshops and professional development courses, do you find there is a difference, compared to the Enrichment Programme you attended at the Science Centre?

**Teacher:** It is totally different experience. Mostly professional development workshops are with teachers and are pitched at higher level. The workshops are not so interesting and it is not with the students. Here, science centre workshops are lined with the student needs and according to the syllabus topics which are taught in the schools. It provides opportunities for us to learn with the students at their level.
Researcher: Do you believe that the Enrichment Programme that you attended should be considered as a part of your personal learning journey as a teachers? It provides all teachers of different backgrounds with the opportunities not only to accompany students for science enrichment programmes, but also learn with them about the lesson as well.

Teacher: Teachers are always learning. This is just one of the platforms. Teachers pick up new concepts, clear their misconceptions, refresh their knowledge, definitely teachers learn when they bring students to science centre. Yes, learn in terms of methodology, in terms of resources available in science centre I don’t think, if we replicate it would be good, difficult to implement. I will try to plan and conduct more hands on lessons in my class. At the same time, I will also try to use examples which trainer used during the lesson.

Researcher: How would you design the Enrichment Programme to be part of the learning journey of teachers? Is there anything you would like to do differently?

Teacher: Thank you very much

Teacher: Thanks.
Appendix XVII: Worksheet (Aquatic Plants and Animals)

Learning Outcomes:

a) To differentiate between terms: organism, population and community.
b) To learn about the different groups of aquatic plants and aquatic animals in a pond.
c) To observe and identify the organisms found in a pond.
d) To identify the roles of various organisms in a food chain and food web.

Introduction:

A pond is a small, enclosed body of freshwater. They are quiet, shallow bodies of water that allow enough sunlight to reach their muddy bottom. The sunlight supports the growth of water plants and algae in the pond. Some water plants grow completely underwater or have parts that extend above the surface. There are plants float on the surface and others grow along the edge of the pond.

Ponds also support a large variety of animals. Pond animals include birds, toads, frogs, fish, insects and turtles. Microscopic organisms also thrive in most ponds. All the organisms interact and depend on each other within the pond community.
Procedures:

Visit the ponds in the Ecogarden.

1. Can you find and identify these plants?
2. Are they floating, partially submerged or fully submerged?

1. ______________________
2. ______________________

1. ______________________
2. ______________________

1. ______________________
2. ______________________

1. ______________________
2. ______________________

1. ______________________
2. ______________________
1. Now can you find and identify these animals?
2. Do you find them on the water surface, above the water surface or in the water?
3. Are they plant and animal eaters, animal eaters or plant eaters?

1.  
2.  
3.  

1.  
2.  
3.  

1.  
2.  
3.  

1.  
2.  
3.  

1.  
2.  
3.  
Can the aquatic plants make their own food?

What do they need to make their own food?
1. 
2. 
3. 

Where do the submerged plants obtain their supply of carbon dioxide?

In what ways do these submerged plants help animals living in the pond?
 a. 
 b. 
 c. 

Using the information you have gathered on pages 2 and 3, complete the following food chains.

Combine the food chains into a food web.
Appendix XVIII: Worksheet (Diversity of Cells)
Cells - the most basic form of life

Every living organism is made up of one or more microscopic cells. Did you know that you were once just a single cell? Two very special cells came together to become one extraordinary cell: YOU! These two special cells came from your mother and the other from your father. We know these cells as the egg and the sperm. These two cells had all the instructions in them to determine how that single extraordinary cell would divide and become specialised to develop into YOU. You have those very instructions in your trillions of cells now. This instruction is in the form of DNA and it is found in a little compartment in the cell we call the nucleus.

The cell is a very busy place.

The cell is like a tiny factory. Its main job is to make proteins. Proteins are essential to the structure, function, and regulation of the body. Where are the instructions to make all these proteins? It is actually within the DNA, which is found in the nucleus. Different parts of the cell called organelles have special roles in ensuring this tiny busy factory is running well, making sure energy is produced for all its activities, nutrients are brought in and waste products are properly rid off.

The organisation and specialisation of cells.

Within multicellular organisms, cells often become specialised for a certain job or function and they look different too. Cells are also organised to form tissues, organs, and organ systems, which form the living multicellular organism. Cells in different kinds of organisms have differences too as they have different jobs to do.

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Activity 1: Preparing a wet mount slide

Procedure:
1. Place a clean dry slide on a flat surface.
2. Place a drop of liquid on the slide.
3. Add the specimen to the drop of liquid (at times, you may want to have the specimen already on the slide before adding the liquid).
4. Hold the coverslip by its sides and lay its bottom edge on the slide close to the specimen. Holding the coverslip at a 45° angle helps.
5. Slowly lower the coverslip so that it spreads the liquid out. If you get air bubbles (looking like little black doughnuts under the microscope), gently press on the coverslip to move them to the edge. If there are dry areas under the coverslip, add a little more liquid at the edge of the coverslip. Too much liquid can be dabbed off with a piece of paper towel.

Activity 2: Using the compound light microscope

A. Eyepiece
B. Needle
C. Objective lens
D. Stage slip
E. Stage
F. XY slide adjustment knob
G. Light switch
H. Light intensity knob
I. Coarse focus adjustment knob
J. Fine focus adjustment knob

*Objective lens (during the practical, use the lens indicated in bold letters):
- Low power objective lens: 4x (red) and 10x (yellow)
- High power objective lens: 40x (blue) and 100x (black)
3. Draw a few yeast cells in the space below including at least one, which is budding.

Yeast cells as seen under 40x objective magnification

4. Draw a few bacteria *Bacillus megaterium* cells in the space below.

*Bacillus megaterium* cells as seen under 40x objective magnification
The chart below is a dichotomous key. It is a method for determining the identity of something by going through a series of choices that leads the user to the correct name of the item. Dichotomous means “divided in two parts”.

In this dichotomous key, cell P, Q, R and S are the four types of cells you had just observed. Fill in the box with the correct cell:

- hydra cell
- human cheek cell
- yeast or
- Bacillus megaterium.

**Has a cell wall**

- Yes
  - Contains chloroplast
    - Yes
      - Cell Q
    - No
      - Cell P
  - No
    - Rod in shape
      - Yes
        - Cell R
      - No
        - Cell S
Activity 4 - Microbe Murder Mystery

A successful businessman is found floating face down in his swimming pool. You and your team of forensic experts are asked to examine evidence to determine if the drowning was accidental or if there is foul play involved.

A team of microbiologists have already examined the water samples from the swimming pool and the two nearby ponds. They observed the microbes under a light microscope and recorded their observations as shown in Figures 1, 2 and 3. It is your job to identify each of the microbes.

Dear fellow microbiologist, you will have to complete the job and help solve this case. Your team has been given three prepared slides of the microbes observed in the water sample from the lungs of the victim. You will need to record your observations and identify these microbes. Finally, compare that sample with samples from the swimming pool and two ponds in the area.

Figure 1: Water Sample from swimming pool of drowned victim (as seen under high power)

Identify the microbe labelled and record it below.

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

Hint: A, B and C have cell walls but only A has a nucleus.
**Figure 2: Water Sample from Pond X (as seen under high power)**

Identify the microbe labelled and record it below.

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3: Water Sample from Pond Y (as seen under high power)**

Identify the microbe labelled and record it below.

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
</tr>
</tbody>
</table>

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DNA 01: Diversity of Cells

Observe the prepared slides given under the microscope and draw a few examples of the microbes observed in Figure 4 below. Label the microbes and identify them.

Figure 4: Water Sample from the lungs of the drowned victim (as seen under high power)

Identify the microbe labelled and record it below.

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

Compare your observations and answer the questions below. (underline your answer)

1. Which is the likely source of the water found in the lungs of the drowned victim?
   - The swimming pool
   - Pond X
   - Pond Y

2. Which is the most possible scene of the drowning?
   - The swimming pool
   - Pond X
   - Pond Y

3. Which is more likely? The drowning was (underline your answer)
   - an accident
   - a murder

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PLANT OR ANIMAL. Look closely at the cells below and indicate whether they are plant or animal cells.
Appendix XIX: Worksheet (Light)

Lab Workshop

Light

Concepts & Content
Energy, Reflection, Refraction, Lens, Mirrors, Rainbows

Objectives
To observe the effects of light:
• Light travels in straight lines.
• Light can change direction.
• Light has different colours.
• Light can be affected by different materials.
1.1 Angle of Reflection

Shine the light at an angle of 30°

a) Which letter does the light beam reflect to?

A  B  C  D
(circle the correct letter)

Shine the light at an angle of 60°

b) Which letter does the light beam reflect to?

A  B  C  D
(circle the correct letter)

c) What happens when the angle of the light beam changes? (circle the correct answer)

The reflection does not move.  The reflection changes direction.
1.2 Mirror Maze

a) Place the wooden blocks on the card/base provided.

b) Arrange 4 mirrors inside the maze so that light can travel from:

A to B

![Diagram of a mirror maze]

c) Draw the position of each mirror inside the maze.

d) Draw the path of light through the maze.

e) What happens when light is reflected? (Circle the two correct answers below)

- It travels in a curved path
- It changes direction
- It continues along the same path
- It stops travelling
- It stays in a straight line
2.1 Lens Shapes

a) Shine 3 beams of light through lens 1.

b) Draw the path of light as it travels out of the lens

![Diagram of lens 1 with light paths]

c) Draw the path of light through the following lens shapes:

![Diagram of a lens shape with light paths]

![Diagram of a rectangular lens shape with light paths]

d) Complete the following sentence

Light travels in straight lines but we can change its ___________ using a lens.

The ___________ the curve of the lens the more light changes its ___________.

Refraction: PART B

2.2 Prism – Making Rainbows

a) Shine a beam of light through the glass prism.

b) Arrange the colours of the rainbow in the correct order:

Orange, , , , , ,

Colour & Energy: PART A

3.1 Colour with Light

a) Mix the following colours of light together and record the colour of light seen on the screen

Red + Blue = Red + Green =

Green + Blue = Red + Blue + Green =
Appendix XX: Observation (Aquatic plants and animals)

Recording Science Enrichment Programme Observation Sheet (For Researcher only)

<table>
<thead>
<tr>
<th>Name of the Programme : Aquatic plants and Animals</th>
<th>Date : 1st Feb. 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the school : YYY</td>
<td></td>
</tr>
<tr>
<td>Class : Primary : 5</td>
<td></td>
</tr>
<tr>
<td>Observer: Researcher</td>
<td>Time: 9.30am</td>
</tr>
<tr>
<td>Duration of Lesson : 2 Hours</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tally</th>
<th>Observing Teacher in the Science Enrichment Programme</th>
<th>Tallies</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>At the beginning of the lesson, the teacher positioned himself/herself</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) at the back of the room</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) together with the students</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) closer to the science educator</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) anywhere else?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualitative description of teacher’s position at the beginning of the lesson:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• on arrival to the Ecolab which is located in the Eco garden teacher approached science educator.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• both greeted each other. Teacher asked science educator how her students are going to sit in the class.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• after listening to the science educator’s instructions, teacher followed the instructions and asked students to sit in a groups of four.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• teacher also changed the sitting arrangement of some students.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• after that teacher stood at the side of the class to listen to the science educator’s introduction.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 2.    | During hands-on activities, the teacher positioned himself/herself |
|       | away from the students |
|       | within the student groups |
|       | closer to the science educator |
|       | anywhere else? |
|       | × | | |
|       | √ | | |
|       | √ | | |
| Qualitative descriptors of teacher’s position during the hands-on activities: |
| • teacher assisted science educator in distributing worksheets and kept one for herself. |
| • while catching animals from the pond, teacher was participating with the whole class. |
| • most of the time teacher was helping and acting like a participant, thus helping, students to catch and observe plants and animals from the pond. |
| • later when science educator started distributing nets and other equipments, teacher helped science educator to distribute the nets. |
3. During the hands-on activities teacher’s interaction with students

(a) away from the students  
(b) interacting within the student groups  
(c) interacting mostly with all groups  
(d) anywhere else?

Qualitative descriptors of teacher’s interaction with the students:
- teacher interacted by taking part in activities with students.
- teacher interacted with students by showing them right way to catch and collect plants and animals.
- teacher interacted with the students by helping students to remove dragonfly from the big net.
- teacher interacted with students by looking at their collection of animals and plants.

4. During the lesson, teacher’s interaction with science educator

(a) away from the students  
(b) interacting within the student groups  
(c) interacting mostly with all groups  
(d) anywhere else?

Qualitative descriptors of teacher’s interaction with the science educator, during the hands-on activities:
- teacher interacted with science educator by introducing herself
- teacher interacted with science educator by asking sitting arrangement of the students
- teacher interacted with science educator by helping to hand out worksheets
- teacher interacted with the science educator by asking certain questions about plants and animals (duckweeds)
- teacher interacted with science educator by asking names of unknown animals.
- teacher also approached science educator to find the difference between great diving beetle and cockroach.

5. During the lesson, photographs taken by teacher.

(a) at the beginning of the lesson  
(b) during the lesson  
(c) at the end of the lesson  
(d) anywhere else?

Qualitative descriptors of teacher’s photograph taken during the lesson.
- teacher took photographs of drawings made by science educator on the board. (types of plants)
- teacher took photographs when students were catching...
flying insects and animals from the pond
- teacher took photographs of animals shown to them by the students (great diving beetle, dragonfly, dragonfly nymph).
- teacher took photographs of plants (water hyacinth, duckweeds and mosquito fern).
- teacher took photographs of pond water and insects under microscope in the lab.
- teacher took photographs of students using microscopes.
- teacher took photographs of students looking at the specimens.

6. During the lesson, teacher’s help in maintaining discipline in the class
   (a) at the beginning of the lesson
   (b) During the lesson
   (c) At the end of the lesson
   (d) anywhere else?

   Qualitative descriptors of teacher’s maintaining discipline in the class
   - science educators were helpful in maintaining discipline in the class
   - there was no need to discipline the class.
   - teachers and students were engaged in doing activities

7. During the lesson Teacher’s behaviour/emotions observed during Enrichment Programme
   - at the beginning of the lesson
   - During the lesson
   - At the end of the lesson
   - anywhere else?

   Qualitative descriptors of teacher’s emotional behaviour observed during the lesson.
   - teacher looked excited and interested, when students were catching the animals in the eco-garden.
   - teacher was interested to know more about plants and animals. For example, some misconceptions about the great diving beetle were cleared. Teacher thought it was a cockroach but while observing specimen closely the concept was cleared.
   - teacher said, Wow! when science educator showed dragonfly nymph on the screen.
   - teacher looked excited to look at the variety of organisms.
### Appendix XXI: Observation (Diversity of cells)

**Recording Science Enrichment Programme Observation Sheet (For Researcher only)**

| Name of the Programme : Diversity of cells | Date : 13/1/13 |
| Name of the school : Clement primary school | |
| Class : Primary 5 | |
| Observer: Researcher | Time: 2.30pm |
| Duration : 2 Hours | |

<table>
<thead>
<tr>
<th>Tally sheet</th>
<th>Observing Teacher in the Science Enrichment Programme</th>
<th>Tallies</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>At the beginning of the lesson, the teacher positioned himself/herself</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) at the back of the room</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) together with the students</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) closer to the presenter</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) anywhere else?</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Qualitative descriptors of teacher’s position at the beginning of the lesson:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher greeted science educator and asked her for sitting position for the students.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher sat at the back with other students because there were only three students in that group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher took one worksheet as it was already placed on the table .</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>During the hands-on activities, the teacher positioned himself/herself</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) away from the students</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) within the student groups</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) closer to the presenter</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) anywhere else?</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Qualitative descriptors of teacher’s position During the hands-on activities:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• initially teacher was seating at the back seat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher was moving around in the lab and observing students</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher was sitting as a participant with the students</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher was taking notes on worksheet (classification of cells and drawing some cells and also adding information for using microscope step by step)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• teacher was filling up answers in the worksheet.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>During the hands-on activities teacher’s interaction with students</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(e) away from the students</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(f) interacting within the student groups</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g) interacting mostly with all groups</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(h) anywhere else?</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Qualitative descriptors of teacher’s interaction with the</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**students, during the hands-on activities:**
- teacher interacted with students by handing out worksheets
- teacher was paying attention to certain students. (teacher was sitting with certain groups)
- teacher interacts with students by sharing with their responses and showing them correct way to look at the specimens.
- teacher interacted by taking part in the activities with students
- teacher was also looking through the microscope and made her own slides.
- teacher interacts by assisting students to conduct activities properly. For example:
  - teacher interacts with students to adjust the microscope
  - plucking the hydrilla leaf
  - drop water on the hydrilla leaf
  - how to remove extra water from the slide
  - helping students to adjust microscope
  - looking at their answers in the worksheet.

### 4. During the lesson, teacher’s interaction with presenter

| (a) | at the beginning of the lesson | ✓ |
| (b) | During the lesson | ✓ |
| (c) | At the end of the lesson | ✓ |
| (d) | anywhere else? | × |

**Qualitative descriptors of teacher’s interaction with the presenter, during the hands-on activities:**
- teacher interacted with presenter by introducing herself.
- teacher interacted with presenter by asking sitting arrangement for students.
- teacher interacted with presenter by helping to handing out worksheets
- teacher interacted with the presenter by looking at the demonstration done by presenter.
- teacher answers questions on behalf of students
- teacher helps students to answer questions
- Teacher asked presenter about type of cells
- Teacher was asking about magnification of microscope or whether they can see DNA under the microscope

### 5. During the lesson, what types of photographs was taken by teacher?

| (a) | at the beginning of the lesson | × |
| (b) | During the lesson | ✓ |
| (c) | At the end of the lesson | × |
| (d) | anywhere else? | × |

**Qualitative descriptors of teacher’s photograph taking during the lesson.**
- teacher took photographs when students were doing activities.
- teacher took photographs of classroom set up.
- teacher took photographs of specimens and PowerPoint
<table>
<thead>
<tr>
<th></th>
<th>During the lesson, teachers were helpful in maintaining discipline in the class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(e) at the beginning of the lesson</td>
</tr>
<tr>
<td></td>
<td>(f) During the lesson</td>
</tr>
<tr>
<td></td>
<td>(g) At the end of the lesson</td>
</tr>
<tr>
<td></td>
<td>(h) anywhere else?</td>
</tr>
<tr>
<td></td>
<td><strong>Qualitative descriptors of teacher’s maintaining discipline in the class</strong></td>
</tr>
<tr>
<td></td>
<td>• Teacher only allocated sitting position at the beginning of the lesson. Science educator maintained discipline in the class</td>
</tr>
<tr>
<td></td>
<td><strong>√</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>During the lesson Teacher’s behaviour/emotions during Science Enrichment Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(e) at the beginning of the lesson</td>
</tr>
<tr>
<td></td>
<td>(f) During the lesson</td>
</tr>
<tr>
<td></td>
<td>(g) At the end of the lesson</td>
</tr>
<tr>
<td></td>
<td>(h) anywhere else?</td>
</tr>
<tr>
<td></td>
<td><strong>Qualitative descriptors of teacher’s emotional behaviour during the lesson.</strong></td>
</tr>
<tr>
<td></td>
<td>• teacher was smiling when her student wore lab coats.</td>
</tr>
<tr>
<td></td>
<td>• teacher was happy and excited to see the specimens under microscope</td>
</tr>
<tr>
<td></td>
<td>• Wow Factor: when science educator showed hydrilla leaf on the screen by changing the magnification. Whole class said wow.</td>
</tr>
<tr>
<td></td>
<td><strong>√</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
</tr>
</tbody>
</table>

Thank you
### Appendix XXIII: Observation (Light)

**Recording Science Enrichment Programme Observation Sheet (For Researcher only)**

<table>
<thead>
<tr>
<th>Name of the Programme : Light</th>
<th>Date : 23rd Jan 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the school : X X Primary School</td>
<td></td>
</tr>
<tr>
<td>Class : Primary : 4</td>
<td></td>
</tr>
<tr>
<td>Observer : Researcher</td>
<td></td>
</tr>
<tr>
<td>Time: 2.30pm</td>
<td></td>
</tr>
<tr>
<td>Duration of Lesson : 1.5 Hours</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tally sheet</th>
<th>Observing Teacher in the Science Enrichment Programme</th>
<th>Tallies</th>
<th>Total</th>
</tr>
</thead>
</table>
| 1. | At the beginning of the lesson, the teacher positioned himself/herself  
   (a) at the back of the room  
   (b) together with the students  
   (c) closer to the science educator  
   (d) anywhere else? | ✓ | |
| | Qualitative descriptors of teacher’s position at the beginning of the lesson: | | |
| | • teacher and science educator greeted each other. | | |
| | • teacher asked science educator for sitting position for the students and sat at the back seat alone. | | |
| | 2. | During the hands-on activities, the teacher positioned himself/herself  
   (a) away from the students  
   (b) within the student groups  
   (c) closer to the science educator  
   (d) anywhere else? | × | ✓ |
| | Qualitative descriptors of teacher’s position during the hands-on activities: | | |
| | • during the hands-on activities teacher moved from one group to another group of students to observe his student. | | |
| | • in each group, the teacher stood among students because there was no extra seat for the teacher to sit. | | |
| | • most of the time helping and acting like a participant, thus taking part in all the activities done by students. | | |
| | • helping students to put lenses at different places. | | |
| | • discuss the activities, for example how light travels from different lenses so that students get ideas fixed in their mind. | | |
| | • teacher was pointing to some students to draw lines on the worksheet properly. | | |
| | 3. | During the hands-on activities teacher’s interaction with students  
   (a) away from the students  
   (b) interacting within the student groups  
   (c) interacting mostly with all groups  
   (d) anywhere else? | ✓ | ✓ |
| | Qualitative descriptors of teacher’s interaction with the students: | | |
| | • teacher interacts by taking part in activities with students | | |
| | • teacher interacting with the students in their discussion. | | |
| | • teacher interacted with students by telling them to put lenses right way and telling students to see the difference. | | |
| | • teacher interacted with the students by placing lenses at different distance to see the effect. | | |
| | • teacher was sharing the concepts of convergent and divergent rays. | | |
| | • teacher was observing the differences in convex and concave | | |
lenses when students were shifting the position of the lenses.
- teacher was observing how the students were using torchlight beam to pass through a prism
- teacher was looking at how the students were filling up the answers in their worksheets.
- teacher guided some of the students to measure angles using a protractor.
- teacher facilitated student groups by asking questions to prompt students to share and record their observations.
- teacher offered assistance when necessary and appropriate to students.
- teacher also was seen informing students not to adjust the switch on the power converter and not to remove the tape on the light box until the last activity set (Colours and Energy)
- teacher asked students to place all materials and equipment back inside the box.

4. During the lesson, teacher’s interaction with science educator
   (a) away from the students
   (b) interacting within the student groups
   (c) interacting mostly with all groups
   (d) anywhere else?

   Qualitative descriptors of teacher’s interaction with the science educator, during the hands-on activities:
   - teacher interacted with science educator by introducing herself.
   - teacher interacted with science educator by asking sitting arrangement for students
   - teacher interacted with science educator by helping to handing out worksheets and teacher took one worksheet for himself.
   - teacher was observed writing important points on the worksheet when science educator highlighted the objectives of the lesson
     For example: To observe the effects of light,
     Including:
     Light travels in straight lines
     Light can change direction (reflection & refraction)
     Light can be have different colours
     Light can be blocked by some materials
     Light is a form of Energy
     Energy causes Work to be done and changes to occur.
   - teacher interacted with the science educator by looking at the demonstration done by science educator. For example, observing solar panel demonstration demonstrated by science educator (when light strikes the panel it causes changes in the material causing electricity to flow and the object to move).
   - teacher interacted with the science educator by answering questions on behalf of students.
   - teacher was observed helping science educator to switch off the lights for the lab during activities.

5. During the lesson, photographs taken by teacher.
   (a) at the beginning of the lesson
   (b) During the lesson
   (c) At the end of the lesson
   (d) anywhere else?
<table>
<thead>
<tr>
<th>Qualitative descriptors of teacher’s photograph taken during the lesson.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• teacher took photographs when students were doing hands on activities.</td>
</tr>
<tr>
<td>• teacher took photographs of classroom set up.</td>
</tr>
<tr>
<td>• teacher took photographs of experiments</td>
</tr>
<tr>
<td>• teacher took photographs of drawings made by science educator on the board.</td>
</tr>
</tbody>
</table>

6. During the lesson, teacher’s help in maintaining discipline in the class
   (a) at the beginning of the lesson
   (b) during the lesson
   (c) at the end of the lesson
   (d) anywhere else?

   Qualitative descriptors of teacher’s maintaining discipline in the class
   • A science educator was helping in maintaining discipline in the class and there was no need to discipline the class.
   • teachers and students were engaged in doing activities

7. During the lesson Teacher’s behaviour/emotions observed during Enrichment Programme
   (a) at the beginning of the lesson
   (b) During the lesson
   (c) At the end of the lesson
   (d) anywhere else?

   Qualitative descriptors of teacher’s emotional behaviour observed during the lesson.
   • teacher looked exited to see the hands-on activities and interested to know more about the light
   • teacher said, Wow! when the rainbow was cast in the class.
   • teacher’s facial expression changed when she saw he his students doing activities themselves.
   • teacher looked excited to see light passing through different type of lenses.
Appendix XXIV: Feedback Form

SCIENCE CENTRE EDUCATION PROGRAMMES
TEACHER FEEDBACK FORM

The questions below are designed to give us feedback to make future programmes at the Science Centre as meaningful as possible. We would therefore appreciate your candid response to help us achieve this aim.
Your details will not be passed onto third parties. The contact information will only be used for clarification purposes or to send you information of upcoming programmes.

Course Name: ____________________________ No. of students ________
Name: ____________________________ Contact Number: ____________________________
School: ____________________________
E-mail: ____________________________

Key: 1 = Poor 2 = Fair 3 = Average 4 = Good 5 = Very Good

How would you rate the following? (please shade the appropriate circle)

Overall impression of the programme content and material.
Effectiveness of the presentation.

INSTRUCTOR
Overall impression of the programme delivery.
Ability to stimulate interest in students.
Clarity of instructor’s explanation.

PROGRAMME
 Appropriateness of information.
Helpfulness of
(a) Laboratory and hands-on activities. (Please indicate NA for lecture demonstrations)
(b) Worksheet
(c) Powerpoint presentation and/or video clips
(d) Instructor demonstration
Overall programme duration
1 = Too long; 2 = Just nice; 3 = Too short

Would you recommend this programme to others in the future?
Yes ☐
No ☐ (why?)

What did you find most helpful or interesting in today’s lesson?

How could the programme have been more useful? What would you add, drop or change?

Any other suggestions/ comments.

Please turn over