2019

The use of ICT by science teachers in middle secondary science education in the Himalayan Kingdom of Bhutan

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This thesis is presented for the degree of

Doctor of Philosophy

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Edith Cowan University

School of Education

2019

Keywords

Bhutan, ICT, science education, middle secondary science teachers, Technological Pedagogical Content Knowledge, quantitative, qualitative.

Preface

I first heard about computers when was in Year 9 (commonly referred as Class IX in Bhutan). I was 16 years of age and was fascinated by this so-called 'clever machine'. I desperately wanted to see and touch this machine. My wish was fulfilled only after two years when I ascended to Year 11. Although it was an alien thing to me, the sight of the computers and getting an opportunity to power the machine 'On' and 'Off' was a rare achievement. In my young mind, I wondered and pondered how that black box and a screen could perform tasks that were seemingly so difficult for us. Honestly, even today, I am still surprised by with what computers can do!

I created my first email account with Yahoo back in 2000, the year that I joined my College to pursue my degree. My actual interactions and use of computers were during those three years of study. Back then we were the first generation of Bhutanese to have access to computers. We felt proud of ourselves in having an email account, even though we never communicated with anyone! Thereafter, computers and associated technologies would influence my life to a great extent.

After I joined the teaching profession in 2005, computers became widely used in schools and offices, and it was obvious for me to utilise them in my teaching. I had always enjoyed using computers and I wanted my students to derive benefits from the technology. I used computers (i.e., especially the Internet) in my lessons whenever it was possible — to make my teaching more enjoyable. My students loved this technology integration. The Internet and computers helped me to explore beyond the knowledge of textbooks and improved my teaching, a big shift away from the traditional chalk and board method. My interest in use of ICT was recognised by the school and I was offered an opportunity to undergo a Post Graduate Certificate in Teaching Information Systems (PGCTIS) — three-month winter program specifically designed for aspiring teachers. This course sharpened my ICT knowledge and elevated my motivation towards technology use.

By 2010, Internet technology became readily available for teachers and students. The Royal Government of Bhutan initiated a mass information dissemination program called *Chiphen Rigphel*. This program was successfully implemented within a span of five years and

it empowered all groups of people to develop ICT skills. Teachers benefited the most from this noble initiative. The empowerment of teachers with ICT knowledge saw an increased use of ICT in classrooms. However, there are teachers in Bhutan who still lack the skills and knowledge to use ICT effectively. While teachers were empowered with basic knowledge and skills, often, ICT is used without realising its full potentiality.

Through my experience and personal interactions, I came to realise that it was essential to conduct a research to understand the ways in which teachers in the teaching learning process are using technology. I was motivated in carrying out this study that would yield a result showing the general attitudes, perceptions, skills and knowledge of Bhutanese teachers in respect to ICT. I was also keen to understand the various types of technologies being used by teachers in the Bhutanese classrooms and the factors that affected ICT implementation. My intention is that this PhD research will assist others understand the patterns of ICT use in the Bhutanese education context. Therefore, facilitating appropriate decisions by the Government in implementations of best practice ICT policies linked to teacher development programs.

Abstract

This research investigated Bhutanese middle secondary science teachers' ICT knowledge, skills, perceptions and attitudes, patterns of ICT use, and associated factors linked to effective ICT implementation in their classrooms. The study was based on the hypothesis that the use of ICT in secondary science education in Bhutan was affected by the teachers' attitudes and perceptions towards the use of ICT; their knowledge and skills related to ICT; their TPACK and the barriers associated with effective implementation of ICT.

The research was primarily an exploratory study accommodating a post-positivist approach employing mixed design of both quantitative and qualitative approaches. A questionnaire survey on a sample of middle secondary science teachers was the quantitative study. Case studies of eight schools consisting of their historical background and performance records, semi-structured interviews with eight science teachers from these schools and focus group of students from three of these schools formed the case studies. The survey questionnaire targeted 189 middle secondary science teachers from a total of 63 middle secondary schools and secured a response rate of 85.7%. The survey questions covered patterns of ICT use in daily life, interest in ICT, confidence in using ICT and application of ICT in science teaching. A set of Technological Pedagogical and Content Knowledge (TPACK) questions (Mishra & Kohler, 2009) were also included to test the level of ICT integration achieved by these teachers.

The findings showed that overall, the teachers possessed moderate levels of ICT knowledge and skills; very few ICT elements were used in the teachers' daily life, and still less were employed in science teaching due to lack of confidence. Although teachers had positive perceptions and attitudes regarding use of ICT in teaching science, many could not fully utilise ICT due to personal and institutional constraints. Teachers were found to use various ICT tools dependent upon their personal competence and confidence. ICT trained teachers used more tools and engaged with more innovation in the classroom, whilst teachers with low ICT competency and confidence exhibited little integration. ICT trained teachers also helped the school management in developing administrative facilities that engaged ICT, and they also involved students in using ICT presentations. Specialised ICT teachers facilitated innovative uses of ICT such as: interactive student-centred teaching; enhanced collaborative student work; improved problem-based and project-based learning. These teachers also shared their ICT

knowledge and skills with other colleagues. Schools with a poor ICT resources often provided less time for professional engagement and therefore, inhibited the implementation ICT in classrooms.

Based on these findings, the research recommended the government to increase funding for ICT in schools to provide: more computer laboratories and extend the professional development opportunities for both pre-service and in-service science teacher contexts.

More extensive research covering other types of educational institutions, more student-focused research, comparison of teacher and student perceptions and linking performance with ICT use were some new research areas suggested for future.

The limitations of sample size and sampling method and difficulties encountered in interviews using social sites in recording the proceedings were two main limitations identified in this study. The sampling and size limitations could affect generalisability of the findings beyond the context of this research.

Declaration

I certify that this thesis does not to the best of my knowledge and belief:

(i) Incorporate without acknowledgement and material previously submitted for a degree or diploma in any institution of higher education;

(ii) Contain any material previously written by another person except where due reference is made in the text; or

(iii) Contains any defamatory material.

Signature: 

Date: 11.11.2019

Acknowledgements

First and foremost, I would like to pay my respects and gratitude to my late Principal Supervisor, Associate Professor Christopher Paul Newhouse. Thank you from the bottom of my heart for all the support provided without which I would not have achieved this work.

I would like to acknowledge my current Principal Supervisor, Associate Professor Geoffrey W. Lummis who has been the main person for helping me complete my thesis. Thank you, 'Dr Geoff', for your guidance, time, expertise and for your genuine support. You are a great teacher and a wonderful person!

My sincere thanks to Associate Professor Glenda Campbell-Evans, Dr. Martin Cooper, Dr. Alistair Campbell and Dr Eileen Slater for their unwavering support when I needed it the most.

Lastly but not the least, my greatest appreciation and love to my wife Tshomo, my daughter Jigme and son Norzin. I genuinely lack words to express my gratitude for the support and encouragement that you all provided. I love you all from the deepest of my heart.

Glossary

AES	Annual Education Statistics
BCSEA	Bhutan Council for School Examinations and Assessment
BIPS	Bhutan Information and Communication Technologies Policy Strategies
CK	Content Knowledge
DEO	Dzongkhag (district) Education Officers
EMD	Education Monitoring Division
GNH	Gross National Happiness
ICT	Information and Communications Technology
MoE	Ministry of Education
MoIC	Ministry of Information and Communications
NEP	National Education Policy
NER	Net Enrolment Rate
NFE	Non-Formal Education
NWAB	National Women's Association of Bhutan
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
REC	Royal Education Council
RGoB	Royal Government of Bhutan
RUB	Royal University of Bhutan
TCK	Technological Content Knowledge
TK	Technology Knowledge
TPACK	Technological Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge
UN	United Nations

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CHAPTER 1: INTRODUCTION

Information and communications technology (ICT) offers a unique opportunity for developing countries to narrow the development gap with industrialised countries. Despite the potential benefits that can be offered by ICT, developing countries face significant obstacles to ICT connectivity and access. Challenges include: a lack of awareness of what ICT can offer; insufficient telecommunications infrastructure and Internet connectivity; expensive ICT access; absence of adequate legal and regulatory frameworks; shortage of requisite human capacity; failure to develop local language content; and a lack of entrepreneurship and business culture open to change, transparency and social equality (United Nations, 2005).

In Bhutan, despite the difficult geographical terrain and the late arrival of computer-related technologies, there has been a rapid spread of ICT. Students in Bhutan are exposed to various global technologies. There exist abundant opportunities for students to harness ICT for the improvement of their learning, and to augment the quality of education by enhancing the teaching-learning process, developing teachers' professional capacity and strengthening the institutional capacity of the education system (Childs, Tenzin, Johnson, & Ramachandran, 2012).

Figure 1.1. Geographical location of the Kingdom of Bhutan. NB: at top left-hand corner (https://aseanup.com)

This chapter begins with a discussion of the background of education, science education and ICT in the Bhutanese education system. This is followed by a discussion of the rationale and significance of the proposed study. Finally, there is a statement of the research problem to be addressed.

1.1 Background

The Kingdom of Bhutan is a landlocked country situated in South Asia and has never been colonised. Located in the Eastern Himalayan region (26°N and 29°N, and longitudes 88°E and 93°E) it is surrounded by Tibet Autonomous Region of China in the north; Sikkim of India and Chumbi Valley of Tibet in the west; Arunachal Pradesh of India in the east; and Assam and West Bengal of India in the south. Bhutan consists of subtropical plains and Himalayan mountains and has one of the most intact biodiversity in the world and some of the world's highest unclimbed mountains. After the Maldives, Bhutan is second least populous country in the South Asian region (World Atlas, 2018). The state religion is Buddhism.

Bhutan changed from monarchy to democracy in 1953 with a 130-member National Assembly, in 1965 a Royal Advisory Council and in 1968 a Cabinet and later with a bicameral parliament since 2008, when the first elections were held. The King of Bhutan (known as the Dragon King) is the head of the country. In South Asia, Bhutan is ranked first in economic freedom, ease of doing business, peace and the least corrupt country. Bhutan pioneered the concept of Gross National Happiness (GNH). This concept was promoted by His Majesty Jigme Singye Wangchuck, the Fourth King of Bhutan in the early 1970s. All developmental processes and policies are guided by the philosophy of GNH. Bhutan has well established diplomatic relationship with most countries in the world.

In the field of education, Bhutan has one decentralised university, the Royal University of Bhutan (RUB), with eleven constituent colleges spread across the kingdom. The education system in Bhutan can be said to consist of two forms: the school-based education system (commonly called modern education) and the monastic based education system. Records exist that the first school was established in 1913 during the reign of the First Druk Gyalpo King Ugyen Wangchuck (Ugyen & Čokl, 2010). However, a comprehensive school based modern education system was introduced only in the early 1960s, although there are records of school-

based education that was offered dating back to 1920, which was then based on British India school system (Childs et al., 2012; Ugyen & Čokl, 2010).

Prior to 1960, monastic education, which included the study of Buddhist religion, astrology, liturgy, philosophy and the fine arts (sculpture, crafting, music and dance) (Gyamtsho, D. n.d.) was the predominant form of formal education available in the country. Although less dominant now, it continues to play a crucial role in providing monastic based education. Currently, there are 388 monastic institutes in the country with 12,389 students (Ministry of Education, 2013).

After the introduction of economic development plans in 1961, modernization of education has been expanding rapidly to address the educational needs required for the socioeconomic development that is relevant to the modern era (Childs et al., 2012; Ugyen & Čokl, 2010). There are now extensive networks of schools and other educational institutions spread throughout the country. This is mainly due to the government's commitment to education. As of 2013, the net enrolment rate (NER) of basic education was estimated at 94% (MoE, 2013) as shown in Figure 1.2. The NER of basic education in 2018 stood at 91.3% (MoE, 2018).

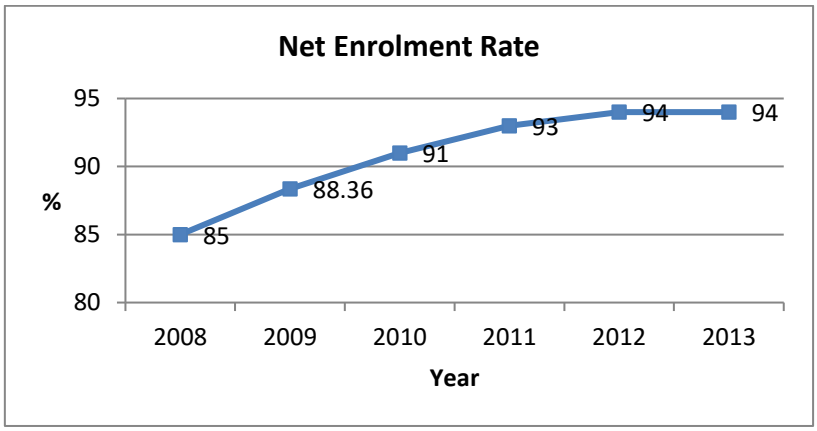


Figure 1.2. Net enrolment rate 2013

Currently, there are 694 schools providing different levels of education that include: extended classrooms (ECRs); pre-primary (PP to Year 6); lower secondary (Year 6 to Year 8); middle secondary (Year 9 to Year 10), and higher/senior secondary (Year 11 to Year 12) education (MoE, 2018). Besides the schools, there are 340 early childhood care and development (ECCD) and 560 educational institutes consisting of special education centres,

vocational training institutes, tertiary institutes, continuing education centres and non-formal education centres all of which provides modern based education (AES, 2018). An illustration of education structure is shown in Figure 1.3.

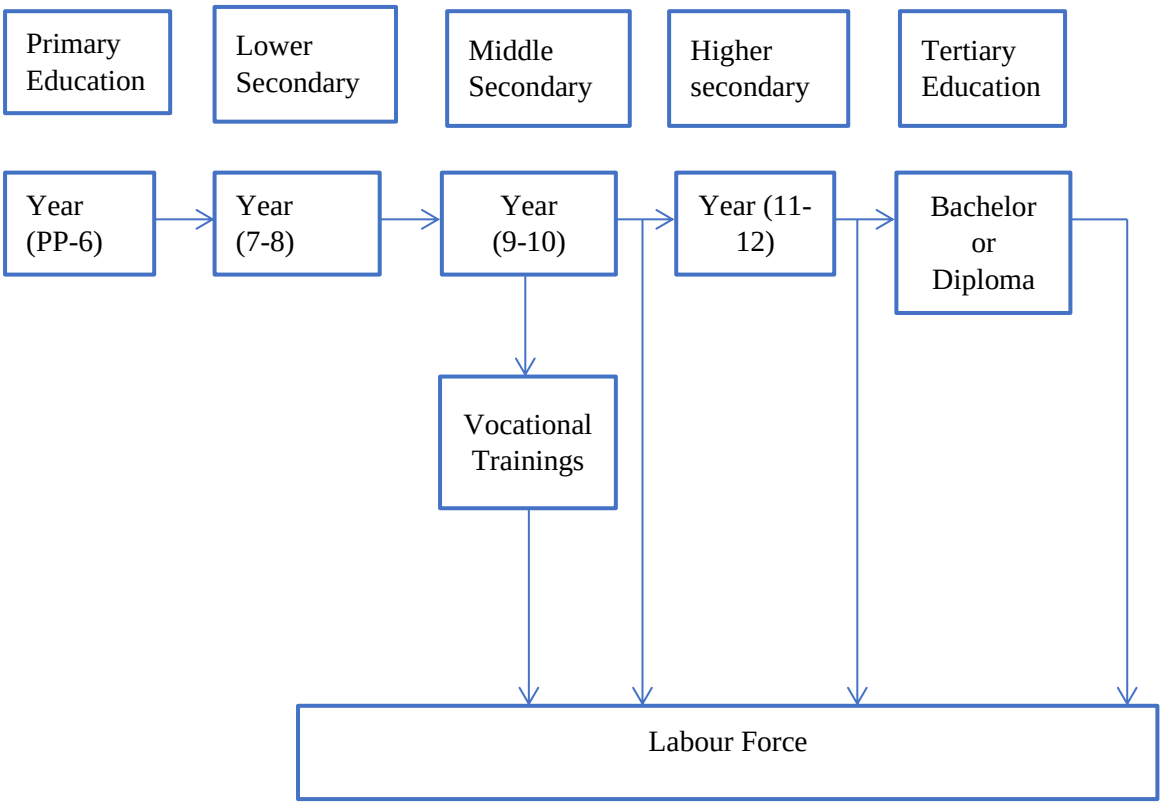


Figure 1.3. The Structure of the education system in Bhutan. (Adapted from UNESCO, Bangkok, 2006)

Education is provided free from PP to tertiary level. This free education covers not only tuition charges but also includes provision of textbooks, stationery, meals and boarding facilities. The Constitution of the Kingdom of Bhutan, Article 9.16 states:

> The State shall provide free education to all children of school going age up to tenth standard and ensure that technical and professional education shall be made generally available and that higher education shall be equally accessible to all based on merit (NEP, 2012, p. 5).

The present education structure in Bhutan can be divided as follows:

- Monastic Education

- General Education (Pre-Primary, Lower Secondary, Middle Secondary and Higher/Senior Secondary)
- Tertiary Education
- Vocational Trainings and
- Non-Formal Education and Special Education

Monastic education is administered by the Central Monastic Body and privately managed independent monasteries. Unlike the schools, Monastic education is provided in the Dzongs (fortresses), Monasteries, Nunneries, Shedras (Buddhist colleges), Lhakhangs (Temples) and Dubdras (meditation centres) that are spread across the country. The curriculum comprises of Buddhist philosophy, logic, astrology, traditional medicine and literature. The language of instruction is either Choekey (classical Tibetan) or Dzongkha. Recently subjects such as English and Arithmetic have been introduced to fulfil the need for skills such as communication in a changing context (Ugyen & Čokl, 2010).

General education is a school-based education that consists of 13 years of pre-tertiary education, comprising seven years of primary education (Year PP to Year 6) and four years of secondary education (Year 7 to Year 10), followed by two years of higher/senior secondary education (Year 11 to Year 12). Education from PP to Year to 10 is the basic education, which is accessible to all students for free, but the access to free education in senior secondary onwards is determined by student's performance in Board Examinations conducted by Bhutan Council for School Examinations and Assessment (BCSEA), as well as by the human resource development plans. Board Examinations are conducted in Year 10 and in Year 12.

After Year 10, students either continue with their senior secondary education (Year 11 to Year 12) or join vocational training institutes or enter the labour market based on their performances in the board examinations. Higher/Senior secondary education is also offered by limited private schools in the country. Similarly, students after completing Year 12 either continue their tertiary education under one of the institutes of Royal University of Bhutan (RUB) for diploma or bachelor's degree or go into the labour market.

Tertiary education in Bhutan is administered by the Royal University of Bhutan (RUB), which was established in June 2003 and currently consists of eleven colleges. In 2018, there were 11,259 students pursuing various degree programmes under RUB (MoE, 2018).

Prior to 2003, tertiary education particularly the bachelor's degrees apart from education was affiliated with the University of Delhi in India. Students join vocational training institutes after they complete their Year-10 studies. Currently there are eight vocational training institutes spread across the country which are administered by the Ministry of Labour and Human Resources under the government of Bhutan.

Non-Formal Education (NFE) or basic literacy courses are offered in all over the country in non-formal education centres to those people who have missed general or monastic education. NFE in Bhutan was established in 1992 under the initiatives of Dzongkha Development Authority and the National Women's Association of Bhutan (NWAB) but is now administered by the Department of Higher and Adult Education under the Ministry of Education. In 2018, there were 6,017 learners in 560 NFE centres across the country. NFE has gained widespread popularity as an effective programme for providing basic literacy and functional skills amongst the adult population, particularly in rural areas (MoE, 2013)**.** Besides the NFE, adults who wish to complete their senior secondary education (Year 12) can pursue their studies through continuing education programmes.

To provide equal access for all children with disabilities and special needs, the government seeks to maintain an inclusive approach to improve educational access and meet the special needs of those with physical disabilities and learning difficulties despite the challenges. There are 22 special institutes with 798 students with special needs (MoE, 2018).

The overall education system, as with the rest of the government system is guided by the nation's development philosophy of Gross National Happiness (GNH) which is propounded by His Majesty Jigme Singye Wangchuck, the Fourth King of Bhutan in the early 1970s. GNH was a concept based on sustainable development in which a nation's progress and development is measured not purely by GDP, but also considers other parameters such as wellbeing and happiness of the citizens. In brief, GNH considers the four main pillars of wellness called the four pillars of GNH: sustainable and equitable socio-economic development; environmental conservation; preservation and promotion of culture, and good governance (e-Government Master Plan, 2014).

The concept for educating for GNH and its realisation in the education system was established in December 2009 with the objectives to:

> effectively cultivate GNH principles and values, including deep critical and creative thinking, ecological literacy, practice of the country's profound, ancient wisdom and culture, contemplative learning, a holistic understanding of the world, genuine care for nature and for others, competency to deal effectively with the modern world, preparation for right livelihood, and informed civic engagement (Educating for GNH conference, 2009, p. 36).

The National Education Policy (2012) clearly mentions the context of GNH education in Bhutan as follows:

> Bhutan's vision of development is based on the principles of Gross National Happiness. As education is the cornerstone of all progress in a society, this vision has been incorporated into the education system through Educating for GNH, an initiative that promotes holistic, contemplative, eco-sensitive, and culturally responsive educational approaches that are both taught and put into practice (p. 5).

1.2 Science Education in Bhutan

The opportunity to learn and interact with science is provided through Environmental Studies in PP to Year 3; General Science in Year 4 to Year 6 and Integrated Science in Year 7 and Year 8. The science curriculum in Year 9 to Year 12 offers science studies through three sciences disciplines: Physics, Chemistry and Biology. The curriculum in Year 11 and Year 12 offers specific science syllabi designed to meet the needs of students for university studies, training and employment.

Formally, science education started with the introduction of modern based education in the 1960s with a curriculum borrowed from its neighbour, India (Childs et al., 2012). In 1986, science education underwent major changes with the launching of a 'New Approach to Primary Education' (NAPE) that brought several changes in the primary science curriculum for Year 4 to Year 6. The new science curriculum was based more on Bhutanese contexts, with consideration of Bhutan's natural and social environment. NAPE also focussed on the development of investigative skills through inquiry as opposed to conventional methods that emphasized the memorization of scientific facts and figures (Childs et al., 2012).

After nearly a decade and a half, NAPE was severely criticised with concerns raised by Bhutanese educators and teachers pertaining to the content in the textbooks and manuals (Childs et al., 2012). Therefore, in 2001, textbooks and manuals were revised to include updated content and teaching materials, particularly to suit those non-science teachers who taught science due to shortages of science teachers in the schools.

Alongside the revision of NAPE, there were also changes occurring in science curriculum for Year 7 and Year 8. Discussions on revision of science in Year 7 and Year 8 started in 1999 and in 2000, sciences in these classes was replaced by a single integrated science "Science for Class VII (Year 7): Learning Science Through Environment" and "Science for Class VIII (Year 8): Learning Science Through Environment" from the three distinctive disciplines (Biology, Chemistry and Physics). Main reasons for these changes were to localize the curriculum and to prevent memorisation of scientific facts and figures; to make learning easy and enjoyable as the three science disciplines contained abstract scientific contents which was difficult for students; and to provide more opportunities for hands-on activities to students that focussed more on scientific skills than the scientific concepts (REC, 2018). It also provided a proper link for Year 7 and Year 8 science curriculum to Year 4 to Year 6 science curricula to form a consistent science curriculum from Year 4 to Year 8 with more emphasis on Bhutanese related contexts and environmental science.

As discussed above, there have been several attempts to renew the science curriculum since the late 90s; however, these earlier attempts addressed only the concerns and issues arising from the fields at different times and did not address the main issue of the fragmented science curriculum, or the lack of progression. Stakeholders and general public raised concerns over declining science standards mainly due to fragmentation and lack of proper science attainment standards at different learning stages. The need analysis survey which was conducted by the Ministry of Education with the support from UNESCO in 2007 showed that there was indeed a lack of progression of scientific ideas across classes. It also found that there was a content overload in higher classes and imbalance of contents in three science subjects (Biology, Chemistry and Physics) and the need for teachers' professional development in both areas of pedagogy and content knowledge (REC, 2018). Therefore, a major curriculum reform from primary to senior secondary was embarked in the 10th Five Year Plan (Gross National Happiness Commission, 2009). This reform brought about the development of a science

curriculum framework from PP to Year 12 and provides an overview of science education in Bhutan. The new science curriculum framework outlines the following objectives:

- provide teachers, learners, parents, employers and educators of higher education institutions with a clear statement of what learners are expected to achieve as a result of their science education from PP to Class XII. It is, therefore, a document of communication to all stakeholders in our society, so that they understand the aims of science education in Bhutan and, at each stage, they can see how these are achieved;
- bring co-ordination, consistency and coherence to the science curriculum;
- guide curriculum developers in designing meaningful learning experiences for learners that are enriching, challenging and relevant to learners and to the country's needs and aspirations.
- provide science education that is developmentally appropriate and reflects a systematic and progressive approach throughout pre-primary, primary and secondary education. (REC, 2018, p.2).

The science learning experiences as stated in the new science curriculum framework are organized into four key elements known as the "Strands" and five key stages of learning. The strands are process strand (Strand 1) and conceptual strands (Strands 1,2, and 3) and they are as follows:

Strand 1: Working scientifically
Strand 2: Life processes
Strand 3: Materials and their properties
Strand 4: Physical processes

Strand 1 focuses on activity-based learning experiences (scientific skills) while the other strands are based on scientific concepts and ideas. The five key stages are:

Key Stage 1: Classes PP to III (PP-Year 3)
Key Stage 2: Classes IV to VI (Year 4 to Year 6)
Key Stage 3: Classes VII to VIII (Year 7 to Year 8)
Key Stage 4: Classes IX to X (Year 9 to Year 10)
Key Stage 5: Classes XI to XII (Year 11 to Year 12)

The new science curriculum framework was developed based on several principles guided by the consultation workshops with relevant stakeholders and global scientific perspectives and theories. Amongst others, developers considered Stage theory of development proposed by Jean Piaget and Bloom's taxonomy of cognitive domain (REC, 2018). Unlike the previous curricula, the new science curriculum emphasized on the importance of ICT in science education across all the key stages of learning. The effective use of ICT was one of the guiding principles that the new curriculum was based upon. The importance of ICT in science education as expressed in the framework is stated below:

> The science teaching and learning process can also be enriched with the purposeful integration of ICT. This has the following benefits: ICT in science classes promotes cognitive acceleration in learners; enables a wider range of experience so that learners can relate science to their own and other real-world experiences; increases the learners self-learning management and facilitates data collection and presentation. Therefore, ICT can play a vital role in supporting the learning of science in areas such as measuring, exploring, investigating, analysing and interpreting. In addition, simulations can be used when an activity is not possible in a science laboratory. The Internet can also be used by the learners to access information and undertake problem solving activities. While using ICT, the learners also develop their skills in a wide variety of ICT applications, which should serve them well in the future. The new Science Curriculum, therefore, encourages the integration of ICT as an integral part of the science teaching strategy as and when feasible (REC, 2018, p.7).

Accordingly, the new science curriculum framework was launched in 2010, designed to encompass new developments and challenges happening in the field of science and more importantly to address the philosophical concept of GNH. New textbooks and teaching materials from Year 3 to Year 8 were written with Bhutanese content aligned with the philosophy of GNH. Unlike in the past, Bhutanese educators and writers were involved in framing the new science curriculum and in writing the new textbooks. Despite the new curriculum being student centred and inquiry-based, most teachers continue to follow the traditional way of teaching in their classrooms. However, with new developments, the trend is fast changing with inclusions of new teaching strategies and pedagogies.

1.3 Overview of ICT in Bhutan

Bhutan launched its first telecommunication network in 1963, but it was only in 1998 that a fully digital national telecommunication network was established connecting all the major towns (Ministry of Information and Communication, 2003). Computers were introduced in the country in the early 1980s. However, the real emphasis on ICT first gained momentum in 1999 with the arrival of television and the Internet. With supportive policies, programs and plans, the Royal Government of Bhutan (RGoB) aims to bring Bhutan to the forefront of technology (Tobgay & Wangmo, 2008). Several Information Technology (IT) related projects have been established to provide access to ICT to all citizens in Bhutan. Some of these are the establishment of Community Information Centres (CICs), Information Technology Park and Chiphen Rigphel Projects. There were more than 185 functional CICs (Gyalsten, 2014) and the Government aims to establish 205 in each Gewog (Block). The Thimphu TechPark is the country's first IT Park developed with support from the World Bank. Currently, two US registered companies; ScanCafe and Shaun Communications, have rented space at IT Park.

Chiphen Rigphel is a human capacity building project designed to help Bhutan for successful transition to an IT enabled society. This project was formally launched in April 2012 with support from the government of India. Since its inception, about 100,000 Bhutanese, including school children, have received IT training under the project.

The three overall policy objectives stated in the Bhutan Information and Communication Technologies Policy Strategies (BIPS, 2004) are: to use ICT for Good Governance, to create a Bhutanese Info-culture and to create a "High-Tech Habitat". ICT vision as reflected in the ICT White Paper (2003) states that "with people at the centre for development, Bhutan will harness the benefits of ICT, both as an enabler and as an industry, to realize the Millennium Development Goals and towards enhancing Gross national happiness" (p. 2).

The Bhutan 2020 (1999) vision document for the country also states:

> The enormous opportunities that exists in the IT and related field should be encouraged and promoted. The priority should be to prepare the IT strategy and activate it. The private entrepreneurs, institutions, schools and other

> interested individuals, should be encouraged to participate in the promotion of this important technology (p. 63).

ICT is still a relatively recent phenomenon in Bhutan. However, the country has seen a rapid rise in ICT use, its access and infrastructure development since the arrival of Internet in the late 90s. There were only about 2000 computers in the entire country in the year 2000 (Tshering, 2013). Until the end of 2006, there was only one internet service provider, Druknet, IT division under the umbrella of a government owned corporation called Bhutan Telecom Limited. In October 2006, Tashi InfoComm Limited, a wholly owned subsidiary of Tashi Group of Companies, Bhutan's first and only private licensed Telecommunications Operator, joined the market to provide telecommunication facilities including the Internet.

According to the World Bank Report (2010) the Internet users per 100 people grew from 0.4 users per 100 people in 2000 to 7.2 users in 2010. In 2014, it is estimated that there were 14 Internet users per 100 Bhutanese people. Latest data in 2017 reveal that there were 475,394 B-Mobile subscribers with 438,307 subscribed for Mobile Internet and 15,921 broadband/lease line subscribers. Similarly, Tashi-Cell has a total of 136,077 subscribers with 10,115 with Tashi-Cell Internet (NSB 2014). While Mobile Internet users have increased from 197,458 in 2013 to 438,307 in 2017, the use of broadband Internet decreased from 20,630 in 2013 to 15,921 in 2017 (NSB, 2017). This change in user preference of Internet could be related to the popularity, affordability and ease of connections associated with mobile connections.

1.4 ICT and Education in Bhutan: Status and the Challenges

Over the past decade Bhutan has been experiencing a rapid spread of ICT, particularly computer related technologies such as the Internet. The Internet is now accessible to almost all Bhutanese people, especially via the cellular network. Bhutanese students are involved in the use of computers, Internet, intranet, instant messaging and cellular phones. The National Education Policy has the following mandates for ICT in education:

- All schools shall be equipped with adequate and relevant infrastructure (hardware, and software);
- All schools shall have high-speed Internet connectivity. Student access to the internet shall be promoted in schools to enhance student learning;
- All students completing basic education level shall be IT literate;

- IT education shall be an integral part of professional development programmes for all the teachers to ensure an IT infused and enhanced curriculum delivery;
- ICT shall be utilised to facilitate and enhance remote learning;
- Collaborative learning using ICT to promote creativity in students shall be facilitated; and
- Schools shall ensure the use of ICT in the school level policy.

Data from the Ministry of Education (2012) revealed that out of 7932 teachers, 3912 teachers had a laptop and 687 had a desktop computer. Gyeltshen (2013), reported that while 245 schools provided Internet access to teachers and students, Internet access for 155 schools was limited to the school administration. Most schools were connected to the Internet through dialup connections, and only 35 senior secondary schools (commonly referred as higher secondary schools in Bhutan) have access to leased lines. One hundred and ninety-four schools had access to use of projectors and 124 schools have scanners, their use in teaching learning processes had no proper documentation. In 2018, there were 180 computer laboratories with 4688 working computers in different schools. The average student-computer ratio was 1:23. Out of 694 schools in 2018, 316 schools had Internet connectivity. This accounted for 53% of schools with Internet connections (MoE, 2018).

Since the modernisation process started in 1961, schools in Bhutan have been undergoing rapid changes including changes relating to technologies. When the first computers were brought to Bhutan in 1984, their use was relatively limited owing to poor electricity supply. Computers were initially used without Internet connectivity until 1999 when the Internet was first introduced (Tobgay & Wangmo, 2008). The two teacher training colleges provide ICT courses to teacher trainees and ICT is one of the main subjects in which the teacher trainees are trained to enable them to effectively use it once they become fully qualified teachers.

There are limited studies available on use of ICT in education in Bhutan. The available studies are either focussed on ICT use in teacher education or general trends of ICT usage in the country. Kinley, Zander, Georgsen, and Choeda (2013) studied the usage of ICT by lecturers in one of the teacher colleges. They found that ICT use helped the lecturers in effective delivery of lessons but the motivation amongst lecturers to use ICT was found to be low. The low motivation levels were attributed to a lack of resources, a lack of support and poor Internet

connectivity. The study also revealed differences between lecturers in terms of ICT competences, professional training, skills and the individual use of ICT for teaching. Tenzin and Bhattarakosol (2013) attempted to study Bhutanese teachers' perceptions of ICT by and its integration into classroom teaching. The study found that while most teachers (89%) possessed ICT skills that could be utilized in their teaching, the actual use of ICT in classrooms was very low (50%). They concluded that the use if ICT by teachers was concentrated around personal use such as entertainment and social networking. However, the study suggested that teachers in Bhutan showed a willingness to learn and integrate technology into their teaching.

1.5 Rationale for this Study

Research in the field of education relating to the use of ICT by teachers in teaching-learning processes has shown that it is beneficial both to teachers and students as it brings improvements in learning outcomes, and helps with the workload of teachers (Diem, 2000; Sutherland, Robertson, & John, 2009). As with any other field of education, the use of ICT in science education has several benefits, such as: enhanced development of students' critical thinking skills; ease of data collection and manipulation; increased access to knowledge in a visual format; and enhanced motivation and engagement (Dawson, 2008; Hennessy et al., 2007). These benefits make both theoretical and practical aspects of science education to be improved by using various forms of ICT. Salihi (2015) cited Bransford, Brown and Cocking (2000) to stress that meaningful learning by students takes place when they create meaningful and understandable knowledge structures based on learning goal. Meaningful learning involves activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These components form the criteria for development and selection of teaching and learning activities with ICT.

Studies also indicate that teachers play a crucial role in effective implementation of ICT in classrooms. It is said that the extent of effectiveness of the use of ICT in the classroom is largely dependent on how teachers use the technology (Incantalupo, Treagust, & Koul, 2013). According to Koehler and Mishra (2009), teaching with technology is complicated considering the variety of technologies used in different ways to enhance learning process of students and the challenges of rapidly emerging newer technologies to teachers.

Research on science teachers' perceptions and use of ICT has revealed that while they have positive attitudes towards the use of ICT in their teaching, there are various barriers that prevent the effective use of ICT in teaching-learning processes (Dawson, 2008; Tenzin & Bhattarakosol, 2013). These barriers are mostly associated with the ICT knowledge and skills of science teachers; and access to resources, support and training (Dawson, 2008). Studies have found that science teachers possessing positive attitudes, competent ICT knowledge and skills, coupled with available resources and support in schools are more inclined to use ICT in a way that will eventually result in improved learning outcomes.

Students' achievements are largely determined by the attitudes, knowledge and ICT skills possessed by science teachers. Equally important to students learning are the types of ICT that is available in schools and the support received from the management. The teacher training institutes also have a role in training science teachers who are prepared to implement ICT effectively.

1.6 Significance of Study

It is important to understand the role of technologies in education. Despite the widespread integration of technologies in education, there remains for educators and science teachers to clearly understand the actual role it plays in enhancing students' learning. The effectiveness of ICT use in education will largely depend on the type of technology being used and the time spent on using a right type of technology for a specific content area of learning. The aim of this study was to investigate the pattern of ICT use in middle secondary science education in Bhutan. It aimed to explore and understand in depth, the ICT knowledge and skills; attitudes and perceptions towards ICT and Technological Pedagogical Content Knowledge (TPACK) of Bhutanese science teachers. It also sought to determine the factors that affect the effective implementation of ICT in science education. To obtain positive impacts, ICT must be effectively implemented in science education. The effective implementation of ICT can only be achieved through the understanding of how ICT is used by teachers and students, and what knowledge, skills, attitudes and perceptions teachers possess. These were the focus for this study.

While similar studies have been conducted in other nations, this has not been done in Bhutan, which is very different in many relevant characteristics to previously studied nations. Therefore, the findings from the study could be used to make recommendations to policy

makers in the Royal Government of Bhutan and the Ministry of Education in making informed decisions relating to investment in ICT and in ICT education. The results from the study may also assist the Ministry of Education to make informed decisions regarding the training and professional development of science teachers that will lead to increased use of ICT to support the science education process. Further, the findings will assist the agencies such as Royal Education Council (REC) and Education Monitoring Division (EMD) under the Ministry of Education in reforming curricula and in providing teacher development programmes that will result in overall development of science education in Bhutan.

1.7 Statement of Research Problem (Purpose)

The research problem, the aims and research questions identified for this study are stated below.

The research problems for investigation:

What are the current levels of knowledge and skills of ICT existing among the middle secondary science teachers of Bhutan and how do they use them in their teaching methods and with what outcomes?

This problem is related to the current levels of knowledge and skills that the middle secondary teachers of Bhutan have and currently, how they use these knowledge and skills in their teaching methods and with what types of outcomes. The answers to these problems are necessary to address the next problem below.

How do the perceptions and attitudes of Bhutanese middle secondary science teachers affect their use of ICT and their outcomes in teaching?

When teachers use their knowledge and skills in teaching, certain outcomes are bound to occur. Therefore, consequently, the experience the teachers perceive, form their attitudes about the usefulness of ICT in science teaching and that may affect their future use ICT in their teaching.

These two research problems lead to the following aspects of study related to the levels of knowledge and skills and related to perceptions and attitudes.

1.8 Aims of Study

The aims of this study were to investigate on

1. The current level of ICT knowledge and skills amongst middle secondary science teachers in Bhutan and how do they use them for teaching and with what outcome.
2. The attitudes and perceptions of middle secondary science teachers towards ICT and how do these impact upon their use of ICT in teaching and with what outcome.

The aims of the study is divided into four objectives framed as research questions to determine the type of data that needs to be collected and methods of their analysis to answer each research question.

1.9 The Research Questions:

1. What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?
2. What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan?

The above first two research questions are directly related to the two research aims and these aims have been explained above.

3. What are the various types of ICT used by middle secondary science teachers and how and to what extent are they being used, specifically in classrooms?

Levels of knowledge and skills of ICT is related to the types of ICT and how they use them for teaching, as was noted by Koehler and Mishra (2009) and by Salihi (2015). This aspect forms the third research question.

4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

Effectiveness of ICT in teaching depends on the factors which promote or prohibit the ICT implementation. This is also related to outcome. Therefore, it is necessary to investigate these aspects and hence, the fourth research question.

1.10 Summary

In this chapter, the background information on Bhutan, its education system, science education, ICT in Bhutan and in its education, were discussed to provide a precise research context. The rationale and significance of this research were outlined leading to the definition of research problems, aims and research questions. The rapidly growing importance of ICT in daily life and in education has produced phenomenal changes in the very concepts of teaching and learning in a positive way both in the developed and developing countries. Bhutan has been a slow starter with ICT and its use in education is foreseen as limited due to many factors. There had not been much research on these aspects related to Bhutan. The aims and research questions were defined based on these perceptions.

In the next chapter (Chapter 2), research works done on the aspects related to the above research questions are reviewed leading to the identification of research gaps which are addressed by the above research aims and questions. The Technological Pedagogical and Content Knowledge (TPACK) framework developed by Mishra and Koehler (2009) is also explained in Chapter 2 followed by the conceptual framework for this research proposed at the end of the literature review chapter. Chapter 3 deals with the methods of data collection and analysis used in this study towards answering the research questions. Both quantitative and qualitative methods of study were used in this research. Chapter 4 describes the quantitative results obtained by using the procedures outlined in the Methodology chapter. In Chapter 5, qualitative results are described. The results obtained by both quantitative and qualitative methods are integrated together and triangulated with literature support leading to the findings answering the research questions in Chapter 6. Chapter 6 also summarises the whole thesis, identifies the limitations of the study and gives recommendations and points to future researches to be undertaken. The whole report ends with main conclusions possible from this research.

CHAPTER 2: LITERATURE REVIEW

The aims of this study were to investigate the level of ICT knowledge and skills, attitudes and perceptions amongst middle secondary science teachers in Bhutan and its usage in teaching learning processes. Four research questions were framed based on the aims. Hence this review of literature will examine what types of researches were done and what findings were obtained on topics directly related to the four research questions. The review of these aspects will lead to formation of a framework for this research to answer the research questions. Before discussing these topics, some definitions of ICT are examined critically leading the selection of a definition suitable for this study.

2.1 Definitions of ICT

There are various definitions for ICT, and its acronym, that are usually based on the context within which it is being used. According to Lloyd (2005) the acronym ICT stands for Information and Communication Technology, or Information and "Communications" Technology. The former singular form represents a process or outcome while the later plural form represents the technology itself. Often, the acronym is expanded in plural form as "Technologies" and written as ICTs to convey for specific devices or processes. Toomey (2001) was cited by Lloyd (2005) to define ICT as:

> those technologies that are used for accessing, gathering, manipulating and presenting or communicating information. The technologies could include hardware (e.g., computers and other devices); software applications; and connectivity (e.g., access to the Internet, local networking infrastructure, and videoconferencing). What is most significant about ICT is the increasing convergence of computer based, multimedia and communication technologies and the rapid rate of change that characterises both the technologies and their use (p. 3).

This is a very exhaustive definition. But such a long definition describing different elements of ICT can confuse the readers. The elements of ICT are given as the hardware, the software and connectivity. Connectivity has two components namely the Internet service provider like Vodafone and Airtel and the accessed internet services like email, blog, social

media etc. The software is connected to internet by service providers, which enables use of email etc.

Nowadays, smartphones are capable of rendering most of the services offered by computers, so that global connectivity becomes an “any time anywhere” phenomenon. The younger generation is particularly adapted to use of smartphones for varied purposes. Therefore, use of ICT involving mobile phones is emerging as a promising pattern of ICT use in schools.

Newman (2004) defines ICT as a term that includes any communication device or application and is any technology that enables communication and the electronic capture, processing, and transmission of information.

According to Pelgrum and Law (2005), ICT is a term used to connote “internet service, media, telecommunication and network-based information services”. In this definition, the authors list the elements of ICT, but do not specify how the elements are related to each other.

Newhouse (2014) defines ICT as any computer-related technology. From this very concise definition, it is not possible to obtain a clear idea on what ICT really means.

These brief definitions fail to capture all the elements of ICT adequately. While the definition of Toomey (2001) is too descriptive, the other definitions are too brief. For a definition acceptable to this research, a via-media between the two extremes needs to be sought. Two such definitions are considered below.

Cavas et al. (2009) define ICT as “technologies that facilitate, by electronic means, the acquisition, storage, processing, transmission, and disseminating of information in all forms including voice, text, data, graphics and video” (p. 21). In this definition, the processes and outcomes of ICT are mentioned. There is no description of what ICT consists of. Thus, the definition lacks essential details.

The United Nations Development Programme (UNDP, 2001) defines ICT as “ICTs are basically information-handling tools- a varied set of goods, applications and services that are used to produce, store, process, distribute and exchange information” (p.2). In this definition, information handling tools can be computers, mobile devices or any other hardware. Goods can include different types of tools. Applications indicates software. Services means

connectivity provided by the internet and services available in the internet sources like email, social sites etc. Production, storage, processing, distribution and exchange of information are the processes enabled by ICT technology. Thus, all elements of ICT are adequately available in this definition.

Out of the above definitions, the definition given by UNDP was chosen for this study owing to credibility of the source as an international organisation. Besides, the definition is adequately brief and descriptive at the same time inclusive of all elements. The integrated application of the devices, systems and services of ICT for educational purposes constitute ICT in education. How the devices, systems and service are used in various educational contexts determine different use patterns. The four essential elements of ICT in education discussed below indicate how these use patterns can differ within the educational system of schools.

2.2 The Four Elements of ICT in Educational Context

There are four essential elements that need to be considered while trying to define ICT in educational context, they are: ICT as an object, as assisting tool, as a medium for teaching and learning and as a tool for organisation and management in schools (Cavas, Cavas, Karaoglan, & Kisla, 2009).

The term object, in the context of ICT "refers to learning about ICT which is generally organised in a specific course. The type of education and the level of students determine what is being learned of ICT" (Monnen & Kommers, 1995; SER, 1998, Pilot, 1998; cited in Jager & Lokman, 1999). The term object when used in computing also represents a "data construct that provides a description of something that may be used by a computer (such as a processor, a peripheral, a document, or a data set) and defines its status, its method of operation, and how it interacts with other objects" (Bing, 2019). What applies to computer can also be applied to ICT as computer is one of the hardware types used in ICT. When ICT is used as an object in schools, the types of data constructs suitable for the learning context of the school needs to be determined. Once, this has been done, it transforms into a pattern of use for the school. The data construct usable by the school are limited by support of top management, financial and human resources and the attitudes of teachers and students. In the words of Dawes (2001), it increases the potential for maintaining and enhancing education across the curriculum and provide greater student-teacher interaction opportunities. The strategies and methods of

teaching used by teachers and learning by students become their use patterns effectively transforming teaching learning processes. This study investigates only the use patterns of teachers.

ICT can be used to prepare assignments and projects, to collect and document data and to communicate and conduct research. When ICT is used for this purpose by the teachers, it acts as an assisting tool (Monnen & Kommers, 1995; SER, 1998, Pilot, 1998; cited in Jager & Lokman, 1999). Various ICT tools are being used by schools to communicate, create, disseminate, store and manage information. The use of ICT tools in this manner by the teachers promote higher order thinking skills, provide creative and individualised options for students to express their understandings and prepare students to deal with ongoing technological change in society and the workplace (UNESCO, 2019).

ICT becomes a medium of teaching when the teacher uses one or more of ICT devices for teaching the lessons. There are various ways in which ICT becomes a medium of teaching. It increases the opportunity for interactive teaching through dialogic interaction between students and teachers (Beauchamp & Kennewell, 2008). ICT promotes students' cooperation for their own benefit (Schulz-Zander, Büchter, & Dalmer, 2002). ICT can also help in replacing the rigid linear and limited-scope with dynamic, creative, productive technology and empowerment of students (Selwyn, 2007). ICT assist teacher to prepare lessons and other teaching materials and adapt the teaching methods to the nature of contents of learning materials for in-class and out of classroom works of students (Bhagat, Chandak, & Deosthale, 2017).

ICT can be used as tool for organisation and management of the school. In their ICTE-MM (ICT in School Education Maturity Model), Solar, Sabattin, and Parada (2013) described ICT leverage as consisting of education management, infrastructure, administration, teachers and students, to support educational processes of schools. The model was validated by data collection by data collection instruments and web tools. International standards and best practices also endorsed the model. Use of ICT for educational management and administrative purposes among teachers of some Malaysian schools was noted by (Hoque, Razak, & Zohora, 2012).

The existence of these four elements in the use of ICT can be identified in the educational context of any country. When ICT is applied in education particularly in schools, there is a

need for learners and teachers to understand and use various forms of ICT. Only by having this knowledge, can learners make proper use of ICT to assist their learning processes and teachers can make its proper use for effective teaching. Thus, ICT can change the way students and teachers learn. With adequate access to ICT, the teaching and learning medium can be altered.

Finally, ICT can also help in effective management of learning in schools that can lead to general improvements in whole school development. In a Spanish study by Sánchez and Alemán (2011) in the case of attendance-based teaching, teachers thought that ICT tools will influence their daily practice more than the way students work. If students do not have the required skills to use ICT, it may be difficult for them to pass the courses. Also, the teachers, in general did not agree that ICT will lead to student uncertainty, divide the classroom groups, involve more workload or extra time efforts. ICT instruments may make it easier to access the course contents and other learning resources easier. ICT tools were perceived as highly helpful tools. Communication and interaction between teachers and students improved, but not as it was expected. Students became more interested in classroom learning when ICT was used and therefore attendance level also improved. Three years of survey of 662 teachers with access to virtual university campus were done. Such dimensions are possible when ICT is introduced and integrated into educational contexts at any level in any country.

How these four elements fit into use of ICT in science education is examined in the following section using published literature.

2.3 ICT in Science Education

With the increasing need for scientific and technological competence in the future, there exists a prominent debate concerning bringing fundamental changes in science education. Research on the use of ICT in science education has shown several key benefits, such as: making science more interesting, authentic and relevant; allowing more time for observation, discussion and analysis; and increasing opportunities for communication and collaboration (BECTA, 2003; Dawson, 2008). Other benefits of using ICT in science include enhanced development of students' critical thinking skills, ease of data collection and manipulation, increased access to knowledge in a visual format, and enhanced motivation and engagement (Dawson, 2008; Osborne & Hennessy, 2003). These benefits can be traced to the four elements discussed above.

ICT offers a range of different tools for use in science learning activities, including: tools for data capture, processing and interpretation, multimedia software for simulation of processes and carrying out "virtual experiments", information systems, publishing and presentation tools, digital recording equipment, computer projection technology and computer-controlled microscope (Osborne & Hennessy, 2003). These forms of ICT are expected to improve both the practical and theoretical aspects of science education. This is clearly the element of ICT as an object, an assisting tool and medium for teaching and learning.

Ross et al. (2010), in their study to examine the past and present educational technology trends, have revealed that the academic performance of students and proficiency in science subjects such as biology can be increased using technology. They found that students' attitudes are positive when technology is integrated as a learning tool. In their study, Luu and Freeman (2010) found that the relationship between ICT and scientific literacy in Canada and Australia revealed similar results showing higher scientific literacy scores among students having prior experiences and confidence with ICT. The scientific literacy scores were also related to how ICT was used in schools. Their study revealed that the way in which computers were used in schools to attain learning outcomes may have more impact on scientific literacy than how frequent the computers were accessed. This relates to ICT as the medium of teaching and learning.

A study conducted by Su (2008) to evaluate the performance of university students who learned science texts by using ICT, revealed that, the application of ICT multimedia in science teaching facilitated students' acquisition of basic scientific knowledge and improved their performance. It also indicated that multimedia technology helped students acquire a better understanding of the targeted science concepts and promoted a positive attitude toward science learning. However, according to Murcia (2012) "to enhance the effectiveness of classroom science, educators must move beyond understanding the technology itself, important as this is, to understanding the impact of the technology on teachers' pedagogy and students learning" (p.227). This finding depicts ICT as a medium of teaching and learning.

The above findings indicate that the use of ICT as a medium of teaching and learning predominates over its use compared to other three elements. If ICT is to be implemented and made effective, the knowledge and skills of teachers will play a significant role. This is the first research question of this research. Some findings in this direction are reviewed below.

2.4 ICT Knowledge and Skills of School Teachers

The effectiveness of technology in classrooms largely depends on how teachers use the technology (Incantalupo et al., 2013). Siorenta and Jimoyiannis (2008, p. 188) asserted that, "the implementations and adoption of ICT in the classroom is influenced by the science teachers' attitudes and beliefs towards ICT".

In Scotland, ICT has become an essential component of the curriculum in primary and secondary schools (Williams, Coles, Wilson, Richardson, & Tuson, 2000). The 5–14 Development Programme or Higher Still are specifically aimed at increasing the core ICT skills of teachers. School teachers of whole UK are trained in ICT skills under the National Grid for Learning (NGfL) and the New Opportunities Fund (NOF) programmes. Despite these programmes, the results of the study indicated relatively low levels of ICT skills and uses among the teachers.

There exists a strong link between ICT use and pedagogy. It is not appropriate to assume that ICT will transform science education without acknowledging the critical role played by the teachers in creating the conditions for ICT supported learning (Osborne & Hennessy, 2003). Integration of ICT in education will require a deeper understanding of teachers' knowledge, skills, perceptions and attitudes towards the use of ICT. As stated by Mishra and Koehler (2009), "there are several challenges of teaching with technology and these challenges becomes more complicated considering the challenges newer technologies bring to teachers" (p. 1017).

In a study reported from Ghana, skills, perceptions and practices of ICT in second cycle institutions were investigated by Buabeng-Andoh (2012). Teachers had low level of ICT knowledge and application skills. Perceptions towards ICT were not significantly positive. A Greek study on primary teachers by Vitanova, Atanasova-Pacemska, Iliev, and Pachemska (2015) showed that basic ICT Competency was low among 25% of the teachers, basic knowledge and skills to operate a computer was found among 17% of the teachers, and 58% of teachers were proficient in ICT competence. According to Vanderlinde, Aesaert, and van Braak (2015) in Belgium, all the three categorised types of ICT use in schools (basic ICT use, ICT as a learning tool and ICT as an information tool were influenced by the teacher-level ICT competencies measured by their levels of knowledge and skills. ICT inadequacy of teachers was one of the barriers identified by Özdemir (2017) for integration of ICT in Turkish schools.

Low ICT competency was detected as a factor affecting teacher education in Thailand (Akarawang, Kidrakran, & Nuangchalerm, 2015). Technological and pedagogical competencies were identified as two subsets of ICT competencies of teachers in the results reported by Almerich, Orellana, Suárez-Rodríguez, and Díaz-García (2016) from Indonesia. Variations among five schools in ICT-related teacher competencies and actual use of ICT in teaching were observed in a Turkish case study by Aydin, Gürol, and Vanderlinde (2016).

Overall, the above review shows that ICT knowledge and skills of teachers are generally inadequate and vary depending upon many contextual factors. This is true even in the case of developed countries with advance education systems and technologies. This problem can be addressed only through appropriate methods to improve their ICT knowledge and skills. Bhutan may be backward in this respect, but the extent to which this factor affects ICT implementation and progress in secondary level education needs to be researched. This work addressed this felt need.

Along with the knowledge and skills, perceptions and attitude of teachers towards ICT has a strong influence on how well ICT is implemented in their classes, even if other favourable factors exist. Hence, this aspect was covered by the second research question in this work. Some researches done in this direction are reviewed below.

2.5 Perceptions and Attitudes Towards ICT Use Among Teachers

Teachers are one of the key components in the learning environment, and therefore, the perceptions and use of ICT by teachers are critical to bringing new developments that are beneficial to the teaching-learning processes. For successful integration of technology in teaching-learning processes, it has been suggested that change must begin with teachers, including pre-service teachers (Diem, 2000; Schibeci et al., 2008). Teachers' educational beliefs are strong indicators of their planning, instructional decisions and classroom practices and teachers are the most influential factors if educational changes are to be fruitful (Siorenta & Jimoyiannis, 2008).

Using structural equation modelling (SEM) on survey data, Teo (2009) validated a technology acceptance model for ICT use by pre-service teachers under training in Singapore. There was direct effect for perceived usefulness, attitude towards computer use and computer self-efficacy on technology acceptance. Indirect effects on technology acceptance were noticed

in the case of perceived ease of use, technological complexity and facilitating conditions. But this study was done on pre-service teachers. In a later study on behavioural intentions towards use of ICT, Teo (2011) obtained positive attitude towards ICT among high school teachers of Singapore. Positive attitude was a variable for intention to use technology model tested by the author.

In an Australian-wide survey of secondary mathematics teachers, Pierce and Ball (2009) observed an overall positive attitude towards use of ICT for teaching mathematics in schools. Over 80% teachers agreed that use of ICT makes mathematics enjoyable for students, as the main reason for their positive attitude. But 57% teachers responded that students would not be motivated to study mathematics just because they enjoyed use of ICT. However, some teachers felt that addition of ICT in addition to regular hand-practice in mathematics wastes time learning the technology and the time available to cover the course will be insufficient. This perception of time was a barrier to positive attitude towards ICT. Unexpected problems with technology was another barrier. In another study by Albirini (2006), Syrian high school EFL teachers were found to have positive attitude towards use of ICT in EFL classes supporting the usefulness of ICT in language teaching.

Using mobile smart phones of educational purposes have fast become an accepted technology due to its convenience of using anywhere anytime. In Cyprus study by Ozdamli and Uzunboylu (2015), teachers had positive perceptions about teaching using mobile technologies, even with inadequate skills for the technology. The study found that both teachers and students were keen to use mobile phones for teaching and learning purposes.

Generally, there is positive perceptions and attitudes among teachers regarding use of ICT in education. This is so even when the level of adoption of low or absent. Clearly, mere positive attitude is not enough for successful high level of ICT adoption. This conclusion from literature review is applicable in the case of Bhutan also, but not evaluated so far. However, one important aspect related to ICT use is the level and extent of its use by teachers. This aspect is an embedded factor in all the research questions of this study and measured using some variables, hence not separately listed. Some works related to level and extent of use of ICT are discussed below.

2.6 Types of ICT Used by Teachers (How and to what extent they are used in classrooms)

The pedagogical orientation of ICT use in schools around the world under the IEA 2006 project was reported by Law and Yuen (2006). Orientation towards lifelong learning, less traditional and connectedness were examined. The survey covered 9000 schools and 22 countries of different educational systems participated. The survey was done on 35000 grade 8 mathematics and science teachers. System-wide ICT in education policy was noted in 20 countries. ICT spending increased in most countries over the last five years. Nearly 100% ICT access in schools across the countries was seen. Schools had certain organisation actions to implement and sustain ICT. Less than 60% teachers were seen adopting ICT in most countries. Science teachers were more likely to adopt ICT. Infrastructure and support staff time, technical and pedagogical support, professional and leadership development of teachers were critical strategies to implement ICT successfully. School factors determining ICT use were the vision of the principle on ICT, student-computer ratio, technical support, pedagogical support and the support of the principal for leadership development. These findings indicate what types of use patterns existed in schools over the world. With policy and increasing funds supports, schools were able to implement context-specific use patterns. The basic requirements were providing computer to students and teachers, training of teachers, infrastructure, workloads, teams and technical and pedagogical support. Methods to increase adoption of ICT by teachers, promoting use of ICT in subjects like science, where there was a quick uptake are the main areas of use patterns. For effective implementation, the principals were expected to have positive vision on the use of ICT in their schools.

In the Netherlands, study by de Koster, Kuiper, and Volman (2012) found that in traditional schools, ICT was primarily applied to extend and support the use of standard teaching materials in mostly teacher-directed activities. In the innovative schools, ICT tools were used primarily for supporting open-ended activities with several input from the students. All five schools aimed to increase motivation, improve learning results, promote self-directed learning and enable differentiation between students as a result of using ICT. But there were distinct differences among the five sampled schools.

In their early career, schoolteachers in Australia tended to use word processing, internet research, email, and power point more frequently and web page design, online discussion

groups, and virtual excursions were used least frequently. Access to internet and computers and confidence, and skills, workload of teachers and behavioural management issues were the factors which determined the type and extent of ICT use (Dawson, 2008).

In another study in Netherlands, Smeets and Ton (2001) found that ICT was mostly used to augment traditional teaching practices rather than learner-centred teaching. The main type of ICT used in both in primary and secondary classes was word processing. More games and adventures, drill and practice and problem-solving were used in primary classes. Internet, simulations, databases and spreadsheets were used in secondary classes. Thus, the use of ICT by teachers in different classes can be different.

Six global types of ICT orchestration for mathematics teaching were tested in a Dutch study by Drijvers, Doorman, Boon, Reed, and Gravemeijer (2010) with eighth grade classes of one Belgian and nine Dutch schools. The six types are: Technical-demo, Explain-the-screen, Link-screen-board, Discuss-the-screen, Spot-and-show, and Sherpa-at-work. In technical-demo orchestration, the teacher demonstrates the tool techniques. In explain-the-screen orchestration the teacher does whole-class explanation using what happens on the computer screen. In the Link-screen-board orchestration, the teacher describes the relationship between what happens in the technological environment and its representation in conventional mathematics of paper, book or blackboard. The whole class discussion took place on what happened on the computer screen in the case of discuss-the-screen orchestration. In the Spot-and-show orchestration, student were asked to reason out by the identification of interesting Digital Mathematics Environment (DME) student work during preparation of the lesson and its deliberate use and this was discussed in the classroom. Sherpa-at-work orchestration consists of a so-called Sherpa-student using the technology to present his or her work or to carry out actions requested by the teacher. The student controlled the technology and all students were able to follow the actions of both the Sherpa-student and the teacher. In the first three types, the teacher had the dominant role. The other three were more student-centred. The types were not isolated but was combined suitably at different frequencies. These orchestration types can be considered as methods of using ICT to teach mathematics.

In a Taiwanese study on elementary and junior schoolteachers, Hsu (2011) found that the teachers using basic ICT tools like word processing less frequently rarely ICT activities to students. On the other hand, teachers creating complicated multimedia materials tend to assign multimedia activities to students more frequently. Frequency of building websites by teachers

was the best predictor for assigning ICT-based sharing activities to students, more in the case of junior high school teachers than elementary school teachers.

The issue of teacher's integration of ICT in classrooms was studied by Donnelly, McGarr, and O'Reilly (2011) using a virtual chemistry laboratory (VCL) application in classrooms. Based on the results, a teacher ICT integration model was presented diagrammatically. The teachers were classified as selective adopter, creative adopter, contented traditionalist and inadvertent user. The first two relate to empowerment/ownership and the last two relate to helplessness/fatalism. Selective adopter and contented traditionalist are more teacher-centred and assessment-focused types. Creative adapter and inadvertent user are student-centred and are learning-focused.

According to the opinion of some Spanish primary and secondary school teachers surveyed by Badia, Meneses, and Sigalés (2013), educational use of ICT was influenced by its utility in the given educational context, teacher support for its use by students, availability and access of ICT in classroom, technological expertise of teacher and access to ICT outside classrooms.

According to Wilson-Strydom, Thomson, and Hodgkinson-Williams (2005), most (93%) of the South African teachers had computers for teaching and 79% of teachers had a computer laboratory at school. Internet access was available to 63% of teachers., meaning ICT could be used as a mediational tool. The teachers who had implemented ICT-integrated lessons about once per month (58%) or less than once per month (57%) had 11 to 20 computers. The remaining 33% of teachers never used ICT-integrated lessons even IF they had more than 21 computers. Thus, access alone does not lead to ICT integration. Similarly, access to internet favoured increased ICT integration, but not always a pre-condition. Extent of ICT integration ranged from less than once month through about once per month and more than once per month. Limitations of number of computers (67%), time to complete the lesson, inadequate skills of learners and time scheduling problems were identified as the barriers to ICT integration. Use of ICT for teaching has resulted in many changes in teaching.

A Belgian study by Tondeur, Hermans, van Braak, and Valcke (2008) showed that teachers with strong constructivist and traditional beliefs were more likely to use ICT. The belief profiles of teachers were related with the use patterns of ICT by them. For any belief profile, the tendency to use ICT as a learning tool was higher than for the other two types of

uses. More teachers with constructivist and traditional belief profiles used ICT as information tool, learning tool or tool for learning basic skills than those who had either of the two belief profiles only. Constructivist belief profile was related with higher frequency of all the three ICT use patterns compared to traditional belief profile. In the case of teachers with undefined belief profiles, there was a linearly increasing frequency trend from using ICT as an information tool to learning tool to basic skills tool.

The effect of knowledge, skills and attitudes about Geographic Information System (GIS) was found to influence their use of GIS in their secondary school geography classes was demonstrated in a Turkish study by Demirci (2009). Teachers had very limited knowledge of GIS and how it can be used in geography classes. Only about 16% of teachers had used GIS in their geography classes. However, the teachers had positive attitude about GIS and its use in geography classes. Lack of hardware, software and data also affected more extensive use of GIS in Turkish schools.

The Survey of Schools: ICT in education was commissioned in 2011 by the European Commission Directorate General Communications Networks, Content and Technology to benchmark access, use of and attitudes to ICT in schools in the European Union 27 (EU27). It was one of a series in the EU's cross-sector benchmarking activities comparing national progress towards the Digital Agenda for Europe and EU2020 goals (EU Growth strategy for the coming decade). The Survey was conducted in partnership between European School net and the University of Liège (Service d'Approches Quantitatives des faits éducatifs, Department of Education). This first survey of its kind took place during January 2011 to November 2012. The results of 19000 responses of surveys done on students, teachers and head teachers of sampled schools across the four countries, were reported by Wastiau et al. (2013). The analytical framework consisted of defining schools' ICT infrastructure; teachers' and students' access to ICT at school; confidence of teachers and students in their digital competencies; training in relation to outcomes and achievements; school strategy and leadership; and opinions and attitudes of school heads, teachers and students. Teachers and students of grades 4, 8 and 11 were selected. The schools were categorised into types according to their status of ICT capabilities. Type 1 referred to highly digitalised with high level equipment, very fast internet and high connectivity with school website, virtual learning environment, email IDs for all teachers and students. Type 2 referred to moderate level of digital equipment, internet fast, moderate connectivity. Type 3 schools with low level of digital equipment and low or no

connectivity. Generally, over the entire EU, type 2 schools dominated with 48%, followed by type 1 schools with 37% and in type 3, there were 15% of the schools. The results are based on 156,634 questionnaire answers from students, 24,522 from teachers and 10,137 from head teachers in 27 countries collected between September and December 2011. Majority of schools had doubled the number of computers, with more laptops in classes per 100 students and fast broadband connectivity during the last five years. The trend was moving towards mobile ICT.

At EU level, 25-35% of students in grades 4 and 8 and around 50% of students in grade 11 were in type 1 schools, actual percentages of such schools differing widely between countries. The confidence levels of teachers and students on their ICT skills were medium to low level, suggesting attention on this matter. There was inconsistent relationship for digital confidence of teachers increasing with increasingly supportive schools from type 3 to type 1.

Tenzin and Bhattarakosol (2013) in their study titled: *Successive Factors of Bhutanese Education-based Computer Technology*, found that while technology use was perceived to be useful by teachers, their use mostly focused on the use of multimedia and documentation management. The study also found that technology use was confined to self-use and most of them had limited access to resources. They recommended that teachers should implement ICT in their teaching provided they had adequate skills.

Types, how and to what extent ICT is used by teachers, has been studied by different researchers from different perspectives. They were mainly on:

1. Type of ICT tools used like Word processing, Spreadsheet, PowerPoint, etc.
2. ICT usage for complimenting traditional methods or as new learning concepts?
3. Types of ICT used in classrooms
4. Teachers as types of adopters using the frames of empowerment/ownership, traditionalist or otherwise, teacher or learner-centred
5. Extent of use of different tools
6. Teacher belief profiles influencing whether they use ICT or not

The only available study on Bhutan was very limited in its scope to cover all aspects related to types, how and to what extent questions. All the perspectives listed above are important in answering the research question regarding Bhutan, but only a few of them have been selected for this research owing to time and resources problems.

Despite teachers possessing adequate knowledge and skills, positive perceptions and attitude and effectively using different types of ICT in the required manner, if inhibiting factors are present, the implementation of ICT may not be fully effective. Equally, promoting factors enhance the chances of effective implementation of ICT in classes. Realising the great importance of both these factors, this study included it as the fourth research question. The following section deals with promoting and inhibiting factors of ICT implementation in schools.

2.7 Factors That Promote or Inhibit the Effective Implementation of ICT In Education

In a Second Information Technology in Education Study (SITES) report on 26 participating countries (Pelgrum, 2001), 66% of school principals and technology experts reported lack of ICT knowledge and skills. Insufficient teacher time, lack of technical support, insufficient training opportunities, poor quality teacher training, lack of interest among teachers and lack of school management support were some possible obstacles to adequate ICT knowledge and skills of teachers.

Among the barriers to use of ICT in classrooms in Australian schools, lack of confidence and competence were two factors related to ICT knowledge and skills of teachers although they were desirous of using ICT (Bingimlas, 2009). In Suadi Arabia, Al-Alwani (2005) reported lack of ICT skills as a serious obstacle to integrate ICT into science education.

In East African primary school contexts, the inhibiting factors for ICT integration were found to be unrealistic policies of ICT, poor infrastructure, lack of teacher competence and confidence. Other factors such as poor incentive for the task, negative perception and beliefs, imposed curriculum and lack of political stability also hindered ICT integration. Furthermore, brain drain, technological illiteracy, lack of public awareness and participation, and poor school leadership also hindered effective integration of ICT (Tedla, 2012).

In Cyprus schools, teachers were not found to use computers extensively and even if used, they are used only occasionally. Personal, professional organisational factors of teachers were identified as the inhibiting factors by Eteokleous (2008). According to the findings of Papaioannou and Charalambous (2011) on attitudes and perceptions of principals, ICT integration in Cyprus primary schools is facilitated or inhibited by internal factors consisting

of inspiring and competent leadership, school-based in-service training on ICT, capable ICT coordinator, incentives to the ICT coordinator, involving primary stakeholders in the integration process, collaboration with the district ICT advisory teacher, competence and knowledge of teachers on ICT, acceptance of the innovation from the teachers by the school management and external factors such as in-service training on ICT based in specialised centres, background knowledge of students on ICT, technical support and maintenance of ICT, time available for principals for the process of ICT integration, number of computers per class, support of innovations from the Ministry of Education and Culture.

Both manipulative and non-manipulative factors which could encourage or inhibit due to their presence or absence in varying degrees were identified by Afshari, Bakar, Luan, Samah, and Fooi (2009) through a review of past research. Non-manipulative factors refer to factors that cannot be influenced directly by the school. Some examples are teacher characteristics, parent and community support, governmental policy and the availability of external support. Manipulative factors include existence of a vision and plan about the contribution of ICT to education, level of and accessibility to the ICT infrastructure, availability of time, to experiment, reflect and interact, support available to computer-using teacher in the workplace, school culture, computer attributes, level and quality of ICT training for teachers and school principals, attitude towards computer and computer competence of teachers, effectiveness of training programme and models used for ICT integration and teacher training on this.

In an Israeli study, Avidov-Ungar and Nagar (2015) used both quantitative and qualitative methods to investigate on to examine how the ICT instructors perceive the encouraging and inhibiting factors of the change implementation. The results showed that the sense of empowerment of ICT instructors improved by enhancing their Program Information Communication Technology Knowledge (PICTK) and Technological Pedagogical and Content Knowledge (TPACK). This sense of empowerment facilitated creation of own viewpoints by the instructor regarding the implementation process and the outcome of the National Information and Communication Technology (ICT) Program in Israel. Therefore, it is useful to encourage ICT instructors to expand their PICTK and TPACK knowledge on the developing ICT program. The encouraging factors of ICT implementation were overall guidance of the implementation process, training and technological–pedagogical guidance, technological infrastructure and financial reward in the order of decreasing frequency of instructors. Lack or absence or poor quality of the above factors were reported as inhibiting factors. In addition,

insufficient technological knowledge and motivation was also listed as inhibiting factor, although adequate levels of these factors were not listed among encouraging factors.

Based on a review, Basak and Govender (2015) found that lack of teacher confidence was associated with a fear of failure, anxiety about ICT knowledge and lack of self confidence in ICT. They also reported that teacher confidence was also linked to lack of technological competence of the teacher in terms of knowledge and skills, negative attitude and resistance to change; lack of effective training; lack of time, lack of accessibility and lack of technical support. All these negative factors contributed to difficulties of ICT integration process into their classes.

All the findings discussed above identified similar factors promoting or inhibiting ICT in education. Some studies found presence or absence of certain factors as promoting or inhibiting adoption and implementation of ICT in education. Some others listed separate factors of promotion and inhibition. The common factors applicable to both developed and developing countries are lack of knowledge and skills of teachers, lack of training, poor incentives, unrealistic policies and non-support from the departments, inadequate involvement of all stakeholders, poor school leadership and time factor. Lack of proper network, lack of political stability, brain drain, power supply problems, poor transportation, technological illiteracy, lack of pedagogical skills and poor connectivity are specific to developing countries. Most of these factors may be applicable to Bhutan. However, the relative presence or absence of any such factors in Bhutanese educational context is an unresearched aspect, which this research has addressed.

A theoretical framework, TPACK, useful for measuring how far ICT has been integrated into teaching was developed by Mishra and Koehler (2009). This framework has been used in this research also for the same purpose: how far ICT has been integrated into middle secondary science education by teachers in Bhutan. Hence, the framework and its components are described in detail below.

2.8 The TPACK framework

According to Mishra and Koehler (2009), there exists complicated relationships between teaching and technology, particularly the social and contextual factors. Often teachers receive no support to integrate technology into their work, they have inadequate or inappropriate

experience with using technologies for teaching and learning. They further note that since many teachers have obtained their teaching qualifications at a time when educational technology was at a very different stage to what it is today, they find themselves ill prepared to use technology in classrooms, and they do not seem to appreciate the value and relevance of technology to teaching and learning. They proposed the Technological Pedagogical and Content Knowledge (TPACK) framework to explain these interactions. The framework describes the complex relationship among three bodies of knowledge: content, pedagogy and technology. The proper integration of these three main bodies of knowledge is supposed to produce the flexible knowledge needed to successfully integrate technology use in teaching. It is noted that:

> TPACK forms the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students; prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones (Mishra & Koehler, 2009, p. 1017).

The TPACK framework as proposed by Mishra and Koehler (2009) explains the sets of knowledge required by teachers to arrive at a meaningful implementation of ICT. According to this framework, the three bodies of knowledge; content, pedagogy and technology must intersect to produce effective technology implementation in classrooms.

TPACK provides a framework on how teachers can integrate technology into their teaching. Therefore, the main principle behind TPACK is the integration of knowledge of technology, pedagogy and content to make teaching effective in diverse circumstances and contexts by teachers. Descriptions of the components of the TPACK framework as described by Mishra and Koehler (2009) are given below with a diagrammatic representation as shown in Figure 2.1.

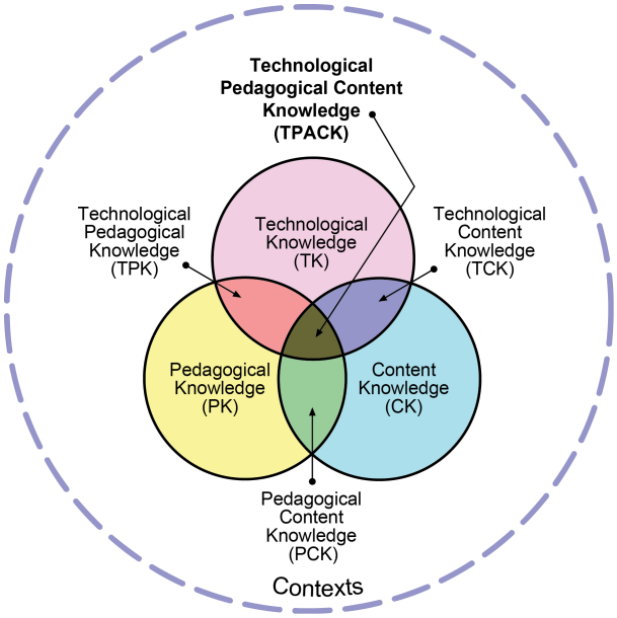


Figure 2. 1. The components of the TPACK framework (Koehler & Mishra, 2009).

The components of TPACK given in Fig 2.1 are explained below.

2.8.1 Content Knowledge (CK)

CK refers to the knowledge possessed by teachers about the subject matter to be taught or learned. The content knowledge is varied because it is based on subject matter or the level of class in focus. For example, the content knowledge in science would include knowledge of scientific facts and theories, the scientific method, and evidence-based reasoning while the content knowledge in arts would include knowledge on art history, famous paintings, sculptures and artists including the aesthetic and psychological theories for evaluating art. It is critical to have a comprehensive base content knowledge since lack of it can lead to incorrect information and misconception about the content area among students.

2.8.2 Pedagogical Knowledge (PK)

PK is the teachers' knowledge on the method and practices of teaching and learning. It applies to teachers' knowledge on how students learn classroom management skills, lesson planning, and student assessment. It considers the knowledge about techniques and methods used in classrooms, the nature of target audience; and strategies for evaluating student understanding. PK also applies to teachers' understanding of how students construct knowledge and skills

therefore, this knowledge requires and understanding of cognitive, social and developmental theories of learning. It is important that teachers know how to use different methods and practices for teaching, science in this research context. Hence, pedagogical knowledge is essential.

2.8.3 Technology Knowledge (TK)

TK is the teachers' technical knowledge of ICT**.** Mishra and Koehler (2009) point out that it is difficult to define TK since it is always in "a state of flux" and any given definition at a time would become out-dated over a period of time. The definition in the framework uses a similar definition of Fluency of Information Technology (FITness), as proposed by the Committee of Information Technology Literacy of the National Research Council (NRC) in 1999.

> FITness goes beyond traditional notions of computer literacy to require that persons understand information technology broadly enough to apply it productively at work and in their everyday lives, to recognize when information technology can assist or impede the achievement of a goal, and to continually adapt to changes in information technology. FITness, therefore, requires a deeper, more essential understanding and mastery of information technology for information processing, communication, and problem solving than does the traditional definition of computer literacy (NRC, 1999).

The above definition highlights the need for one to understand and adapt the technology sufficiently for its effective use. The elements constituting this understanding are information sourcing and acquisition, processing, using for communication and solving problems. These aspects go beyond mere computer literacy.

Mishra and Koehler (2009) strongly believe that acquiring TK in a manner stated in FITness would enable a person to accomplish a variety of different tasks using information technology and to develop different ways of accomplishing a given task. This component is specifically associated with the need to have adequate technical knowledge to effectively use ICT in classes, in science here.

2.8.4 Pedagogical Content Knowledge (PCK)

PCK is knowledge of pedagogy that is relevant to teaching specific content. It is the transformation of the subject matter to teaching and includes how the teacher interprets the subject matter, finds different ways of representations and adaptations, and they ways in which they cater instructional materials to alternative conceptions and students' prior knowledge. PCK forms the central idea of teaching, learning, curriculum, assessment and reporting (Mishra & Koehler, 2009). This component connects pedagogy with content. How the subject matter of learning is converted into teaching methods is very important and is especially so in the case of science teaching as in this research context.

2.8.5 Technological Content Knowledge (TCK)

TCK is an understanding of the way technology and content influence and constrains one another. TCK demands deep understanding of the way a subject matter can be changed by the application of technologies besides the mastery of the subject being taught. Teachers need to understand which specific technologies are best suitable for addressing subject matter learning in their domains (Mishra & Koehler, 2009).

It is essential to understand the impact of technology on content knowledge because only then can teachers develop appropriate technological tools for educational purposes. The choice of technologies affords and constrains determine the types of content ideas that can be taught. Similarly, certain content decisions can limit the types of technologies that be used. While technologies can constrain the types of representations, it can also afford the construction of newer and more varied representations (Mishra & Koehler, 2009). This component connects technology with content. Knowledge of how technology impacts content is essential for appropriate application of the right technology for the right content, in science teaching as in this research context.

2.8.6 Technological Pedagogical Knowledge (TPK)

TPK is an understanding of how teaching and learning can alter when technologies are used in a particular way. TPK relates to pedagogical practices based on affordances and constraints of range of technological tools. To obtain TPK, a deeper understanding of the constrains and affordances of technologies and the disciplinary contexts within which they function is needed;

a particular technology which works effectively in a particular disciplinary context may not necessary give a similar positive result in another disciplinary context (Mishra & Koehler, 2009).

Mishra, Koehler, and Cain (2013) state that TPK is particularly important since most of the popular software programs that are available today are not designed for educational purposes. They further state that, "TPK requires a forward-looking creative and open-minded seeking of technology use, not for its own sake but for the sake of advancing student learning and understanding" (p. 16). This component connects technology with pedagogy. It means, using technological methods for alternate teaching methods for increasing effectiveness. Unless these two components are joined together, teaching methods will remain in the traditional forms only. Not using technology, with which the new generation is so familiar, will demotivate students from learning the subject. Therefore, this aspect is important and is a part of this study too.

Having understood what is TPACK and its components, now some examples of how it is used in practice are reviewed in the following section.

2.8.7 How TPACK is relevant to science teaching in schools

Technological pedagogical and content knowledge (TPACK) provides a dynamic framework for describing knowledge required by teachers for designing, implementing, and evaluating curriculum and instruction with technology. TPACK-facilitated strategic thinking leads to determining when, where, and how to use domain-specific knowledge and strategies to guide learning of students with appropriate ICT. These observations were made in a review of current status of TPACK research by Niess (2011). The author reviewed many models of TPACK proposed by different authors including the one presented above. The training programmes for teachers to introduce technology in teaching involves teaching them the mechanism of incorporating the elements of TPACK. The four components of TPACK required by teachers to introduce technology can be described verbally as: knowing what it means to teach a particular subject matter context; knowing instructional strategies and representations for teaching the particular subject matter topics in the context; knowing the current level of students' understandings, thinking, and learning in specific content areas and knowing what is the curriculum and curriculum materials required for learning in specific subject matter

contexts. Specific programmes for development of TPACK for enquiry-based online learning environment have been studied.

The validity of TPACK in relation to pedagogical training of primary school pre-service teachers was tested by Chai, Koh, Tsai, and Tan (2011) in Singapore. Pedagogical knowledge had a direct impact on TPACK at the beginning of the course. During the progress of the course, teachers made connections between their technological knowledge and pedagogical knowledge leading to technological pedagogical knowledge. The direct relation between pedagogical knowledge and TPACK was replaced by more complex and stronger relationships between pedagogical knowledge and technological pedagogical knowledge and between technological pedagogical knowledge and TPACK. The perceived relationship between content knowledge and TPACK changes was perceived to change from insignificant to significant by the pre-service teachers as they progressed through the course.

In a study conducted in the United States by Guzey and Roehrig (2009), on development of TPACK, technology, pedagogy and content knowledge among four in-service secondary teacher trainees of a technology development programme for ICT integration in K-12 classrooms, a varying degrees of positive impact of the programme on TPACK development of teachers was observed. The ability of teachers to apply in classrooms what they have learned was affected by contextual and pedagogical reasoning.

Graham et al. (2009) noted that science educators use technology to transform science content as well as their pedagogical practices. They may speed up time via simulations of natural events using geological animations; save time through data collection devices and/or recording data, which are usually difficult to collect as with digital probes; see things that not otherwise visible using for example, digital microscopes and organise data in an easier way using spreadsheets, graphical visualization models etc. In their study, trainee teachers began with high level of confidence (mean survey response to the items of confidence) were highest for TK, followed by TPK, then TPACK, and lowest for TCK. Technologies used in science teaching may be unrelated to it (Word, Spreadsheets, etc.), specifically designed for science teaching (simulations, animations, etc.) or required to do science (probes, digital microscopes etc). The patterns of mean scores indicated that the teachers were more confident with applications of technology designed for teaching science than for doing science. General pedagogical strategies were favoured from content-specific strategies by teachers. This could

indicate fitting technology in traditional teaching rather than using technology as a completely new method.

Harris and Hofer (2017) discovered that K-12 schools and districts in the US have increasingly been adopting TPACK framework for professional development of teachers. Context and professional culture were important in this respect. Seven schools/districts participated in the study. TPACK served as a connector, an initiative at the grassroot level, a system of checks and balances, an instructional planning tool, a technological focus, a compass and a collaborative process.

In a case study, TPACK was used by Evans, Nino, Deater-Deckard, and Chang (2015) to describe the process of implementing 'The CandyFactory'-an iPad-specific learning game that focuses on pre-algebraic concepts, especially fraction knowledge, successfully. The findings may be useful for schools and school districts, which are considering adoption of game-based learning and other types of mathematical learning games in classrooms for improved engagement and performance.

All these studies demonstrate the usefulness of TPACK as framework to evaluate the teachers' efforts to integrate ICT into education, especially science subjects, in schools. This study will also use this framework for evaluation of the factors which lead to success/failure of ICT use in Bhutanese middle secondary school science education.

2.9 Research Gaps Identified for this Study

Although there had been several studies on knowledge, skills, attitudes and perceptions, and types and methods of using ICT in schools, there had been practically no research related to Bhutanese schools. This research was the first attempt to fill this gap.

How this gap was addressed by this research has been described by proposing a conceptual framework, aims and research questions in the following sections. The methods adopted to answer the research questions are dealt with in Methodology chapter subsequently.

2.10 Conceptual Framework

The review of the literature was used to develop a conceptual framework for the proposed study. This is represented diagrammatically in Figure 2.2. The purpose of using any kind of

technology in education is to bring about improved learning outcomes, as represented at the bottom of the diagram. To achieve desired learning outcomes, the technologies must be used in a meaningful way; in the right context and situations. The implementation of technologies in an effective way is affected by several factors; such as teachers' knowledge and skills, their attitudes and perceptions towards technologies, and their TPACK. Furthermore, there are barriers to use technologies effectively even if teachers possess appropriate TPACK (Mishra, Koehler, & Cain, 2013). One aspect of this study, Research Question 4, deals with the possible barriers as well as promoters.

The conceptual framework for this study was based on the assumptions (hypothesis) that the use of ICT in middle secondary science education in Bhutan was affected by: the Bhutanese science teachers' attitudes and perceptions towards the use of ICT; their knowledge and skills related to ICT; their TPACK and the barriers associated with effective implementation of ICT. As shown in Figure 2.2, improved learning outcomes can only be achieved through effective implementation of ICT. For ICT to be used in an effective manner there must be a proper understanding of the barriers that inhibit its effective use. In addition, effective implementation of ICT can only be achieved with in-depth understanding of teachers; knowledge, skills, attitudes and perceptions related to ICT.

Based on the above understanding, this study explored: the ICT knowledge and skills amongst Bhutanese science teachers; their attitudes and perceptions towards use of ICT in science education; their TPACK, and the barriers to use ICT in an effective manner in teaching learning process of science. The research problem, the aims and research questions identified for this study are restated below.

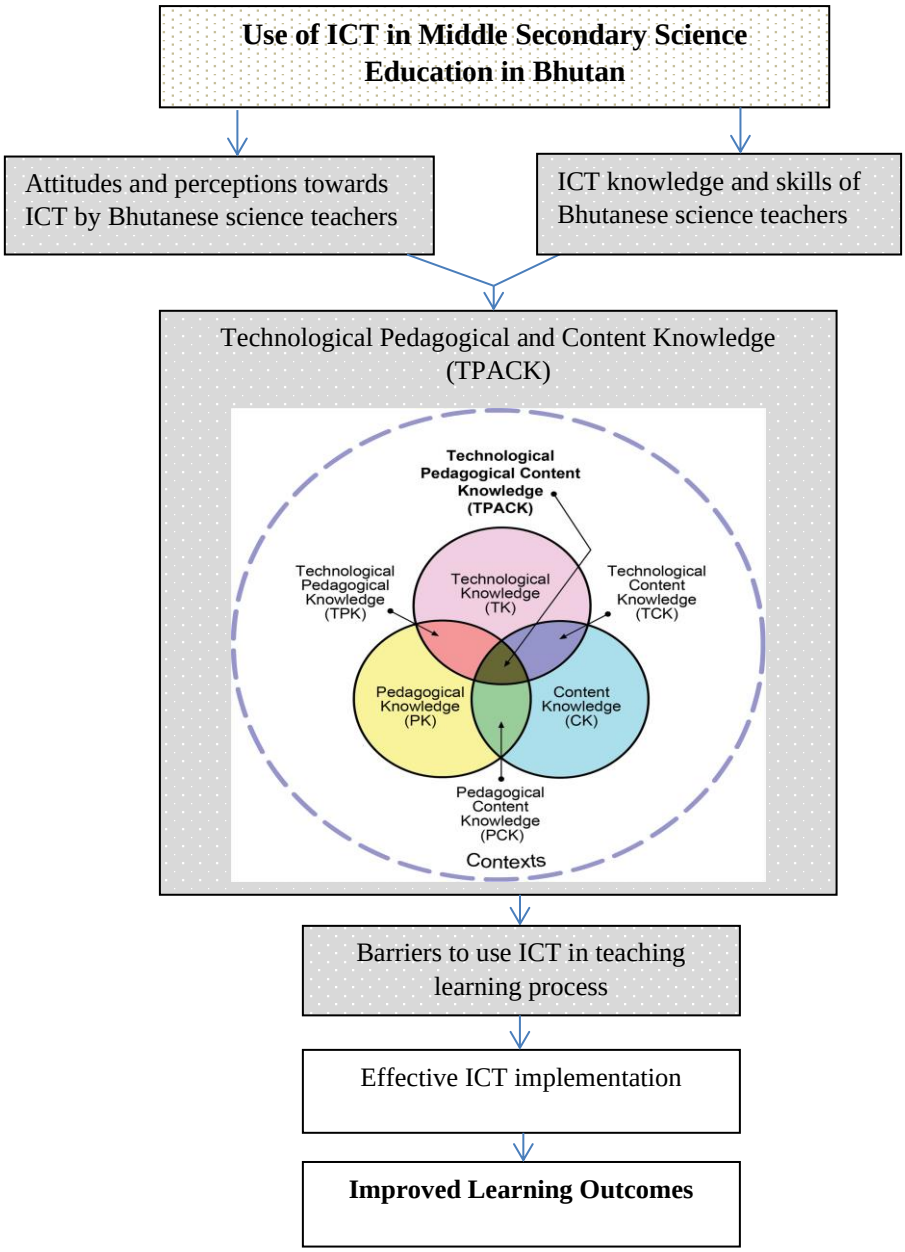


Figure 2. 2. Conceptual framework

The research problems for investigation

What are the current levels of knowledge and skills of ICT existing among the middle secondary science teachers of Bhutan and how do they use them in their teaching methods and with what outcomes?

How do the perceptions and attitudes of Bhutanese middle secondary teachers affect their use of ICT and their outcomes in teaching?

Accordingly, the aims of this study were to investigate on:

1. The current level of ICT knowledge and skills amongst middle secondary science teachers in Bhutan and how do they use them for teaching and with what outcome.

2. The attitudes and perceptions of middle secondary science teachers towards ICT and how do these impact upon their use of ICT in teaching and with what outcome.

The Research Questions

1. What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?

2. What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan?

3. What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms?

4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

The conceptual research work based on the above aims and research questions and incorporating the TPACK components (Fig 2.1) is presented diagrammatically in Fig 2.2. This framework uses an analytical, rather than a synthetical approach to understand the current pattern of ICT use by middle secondary education in Bhutan based on the level of knowledge and skills of the teachers and their perceptions and attitudes towards the use of ICT. Use of TPACK can explain these relationships in terms of technological, pedagogical and content knowledge. Such an analysis will facilitate identification of promoters and barriers to successful implementation of ICT in education. With the identification of these factors, methods to remove barriers and increase promoters can be devised, eventually leading to improved outcomes.

The methods adopted for collection and analysis of data for answering the research questions of this study are described in the next chapter, Methodology.

CHAPTER 3: METHODOLOGY

The purpose of this study was to investigate the use of ICT in middle secondary science education in Bhutan. The study aimed: to understand the attitudes and perceptions of science teachers towards the use of ICT; their ICT knowledge and skills; their TPACK, and promoters and inhibitors associated with use of ICT in secondary science education. Based on the findings, the study sought to explain the relationships between science teachers' attitudes and perceptions with their ICT knowledge and skills, their TPACK, and level of ICT implementation in science education in middle secondary schools in Bhutan.

3.1 World View or Paradigm

The researcher has a post-positivist view. According to Cresswell (2007),

> this approach has the elements of being reductionistic, logical, an emphasis on empirical data collection, cause-and-effect oriented, and deterministic based on a prior theory. Likely view inquiry as a series of logically related steps, believe in multiple perspectives from participants rather than a single reality, and espouse rigorous methods of qualitative data collection and analysis. They will use multiple levels of data analysis for rigor, employ computer programs to assist in their analysis, encourage the use of validity approaches, and write their qualitative studies in the form of scientific reports, with a structure resembling quantitative approaches (p.20).

The methods of data collection and analysis closely aligns the above description and hence the research philosophy here is post-positivist.

3.2 Research Design

To address the research questions, a mixed methods approach using explanatory sequential design was adopted (Cresewell et al., 2011; Creswell, 2005). A mixed methods research design involves collecting, analysing, and "mixing" both quantitative and qualitative research and methods in a single study to understand a research problem (Creswell, 2005). Mixed methods approaches are increasingly being used in educational research (Teddlie & Tashakkori, 2009).

A mixed methods approach was adopted since it provided a better means of addressing the research problem than either type in isolation, and also gave the opportunity to build on the strengths of both quantitative and qualitative data (Creswell, 2005). Utilising mixed methods enables one "to obtain more detailed specific information than can be gained from the results of statistical tests" (Creswell, 2005, p. 516). Further, a mixed methods approach was deemed suitable for this study as when both quantitative and qualitative data, together, better address the research problem than either type by itself; when one type of research (qualitative or quantitative) is not enough to address the research problem or answer the research questions; to incorporate a qualitative component into an otherwise quantitative study; and to build from one phase of a study to another (Creswell, 2005). Therefore, its use is justified in the present context of study to understand in-depth the pattern of ICT uses in secondary science education in Bhutan.

Mixed methods research utilises both quantitative and qualitative processes and techniques. Quantitative research usually decides what to study; asks specific, narrow questions, collects quantifiable data from participants (a large number of participants); analyses these numbers using statistics; and conducts the inquiry in an unbiased, objective manner (Cresewell et al., 2011). It attempts to quantify variables of interest with questions that are measurable. It generally involves collection of numerical data that can be subjected to statistical analysis. The numerical data are collected using various methodologies such as Performance Tests, Personality Measures, Questionnaires and Content Analysis.

On the other hand, for qualitative research the researcher relies on the views of participants; asks broad, general questions; collects data consisting largely of words (or text) from participants; describes and analyses these words for themes; and conducts the inquiry in a subjective-manner (Creswell, 2005). Qualitative research generally involves listening to the participants' voice and subjecting the data to analytic induction (e.g., finding common themes). Compared to quantitative research, qualitative research is more exploratory in nature. Qualitative data are collected using various methods such as interviews, open-ended questionnaires, observations, content analysis and focus groups.

The current study adopted the explanatory mixed methods design (explanatory sequential design) as illustrated in Figure 3.1 involving collection of data in two phases, or sequences.

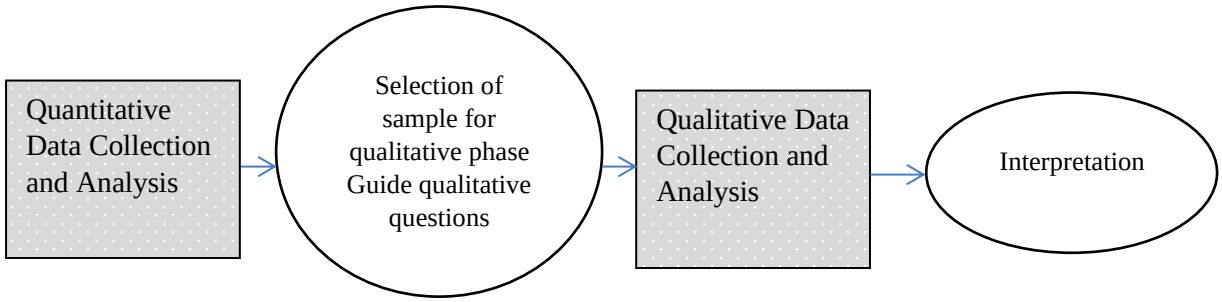


Figure 3.1. Explanatory sequential design

Quantitative data was collected in the first phase followed by the collection of qualitative data in the second phase to help explain or elaborate on the quantitative results. By doing this, it was expected that the results obtained from quantitative data (statistical results) can be refined to explain in more detail through qualitative data. This design (explanatory sequential design) has been chosen since it provided the advantage of clearly identified quantitative and qualitative parts. This design also "captures the best of both quantitative and qualitative data-to obtain quantitative results from a population in the first phase, and then elaborate these findings through an in-depth qualitative exploration in the second phase" (Creswell, 2005, p. 516).

These reasons formed the rationale behind selecting this specific design for the current study. Figure 3.2 illustrates how the sources of data relate to the research questions and how their analyses will inform the findings.

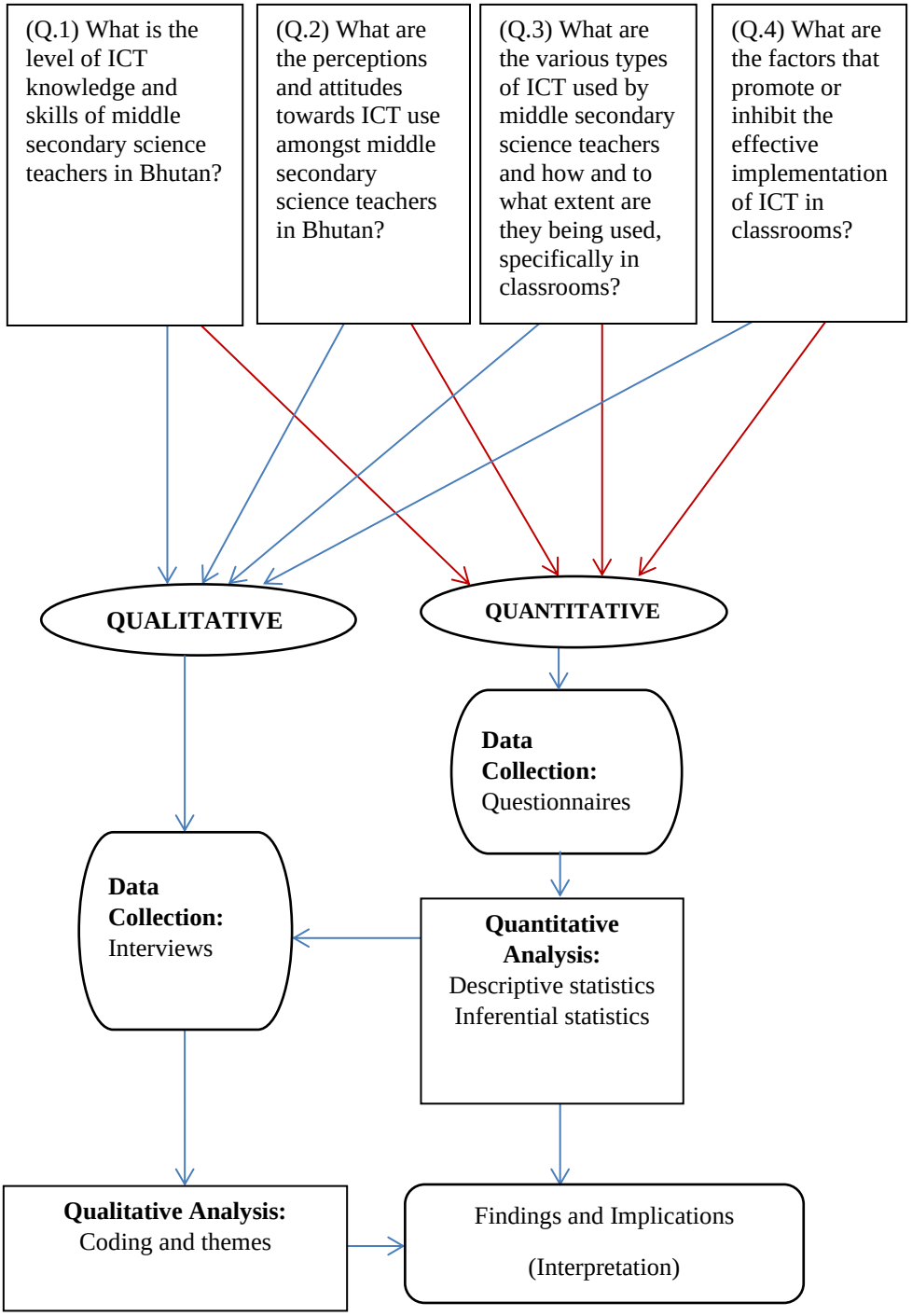


Figure 3.2. Schematic of research design associating research questions with data sources (Adapted from Al Harbi, 2014).

3.3 Population and Samples

A population is a group of elements or cases that may include individuals, events, organisations or units who have the same characteristic and to which research results can be generalised (McMillan & Schumacher, 2010). The target population for this study was all middle secondary

science teachers in government schools in Bhutan. There were 63 middle secondary schools during the time of data collection for this study (AES, 2014).

3.3.1 Identification of the population

As aforementioned, there are three levels of secondary schools in Bhutan; Lower Secondary Schools (Year 7 to Year 8); Middle Secondary Schools (Year 9 to Year 10); and Senior secondary Schools (Year 11 to Year 12). The sample frame was based on the information maintained by the Ministry of Education. According to the Annual Education Statistics (2018), there were 63 lower secondary schools, 77 middle secondary schools and 42 higher secondary schools under the Ministry of Education (excludes private schools). In these schools, there were 6,922 teachers (Male: 3,966; Female: 2,956). No data exists for actual number of science teachers, but it was expected that each secondary school would have a minimum of three science teachers for each science subject (Biology, Chemistry and Physics). In 2018, it was expected that total number of middle secondary science teachers was more than 230 in the country.

The total number of students in any secondary school ranges from 500 to 1200 in an academic year. Information from various agencies under the Ministry of Education, such as: The Royal Education Council (REC), and the Education Monitoring Division (EMD) were utilised to determine the actual sample frame for the study.

3.3.2 Determining the sample size and sampling methods

The sample size is a critical consideration when conducting and evaluating research (McMillan & Schumacher, 2010). The question of sample size was also important because the use of excessively large sample size than the minimum needed size will be a waste research funds and participants' time (ethical issue). Similarly, sample sizes smaller than the minimum required may not provide scientifically valid answers. Then, the research done becomes a waste of resources and participants' time (scientific and ethical issues) (Francis et al., 2010). Too large a sample might become unwieldy and too small a sample might unrepresentative (Cohen, Manion, & Morrison, 2000, 2007). In particular, the sample size is more important in mixed methods since it involves both quantitative and qualitative phases of study (Collins & O'cathain, 2014). In this study, all middle secondary science teachers formed the sampling frame. Therefore, from 63 middle secondary schools (AES, 2014), 189 science teachers were

randomly selected and were sent survey questionnaire. Out of this 189, usable response was obtained from 162 teachers giving a response rate of 85.7%.

Since the current study involved sequential design (quantitative phase followed by qualitative phase), nested samples were applied. This technique was similar to those applied by Al Harbi (2014) in her study. Nested samples involved the selection of a representative sample for the qualitative phase from the sample chosen for the quantitative phase.

In the qualitative phase, case studies on eight selected schools was done. Eight teachers were selected out of the survey respondents. The selection was based on their ICT scores obtained in relation to science teaching and their TPACK score. These teachers were selected since they belonged to a group that utilized ICT in their teaching more often than others. It was expected that they would offer more insights of ICT usage across daily and professional activities of middle secondary science teachers in Bhutan. The corresponding schools of these teachers were used for case study. Three focus group consisting of four to five students taught by three teachers were randomly selected and invited to participate for each of the eight case schools as a part of the case study. Although the intention was to involve eight groups of students belonging to eight teachers, only three focus group was conducted. There were two main reasons: a) some teachers were reluctant to involve their students (consent was denied) and b) some of the schools were in far off places in Bhutan and it hindered the access considering the time and finance. This approach as a case study was done to answer the research question on promoters and barriers to ICT implementation and to collect additional data (as some data have already been collected from the survey) on knowledge, skills, perceptions and attitudes of teachers about ICT in science education to strengthen the findings of quantitative study on these aspects to increase the preciseness of answers to the other three research questions. Although interviews provided the answers to patterns of ICT use by them, the teachers did not have varied ICT experience and therefore cannot be measured precisely from the interview responses.

3.4 Data Collection Techniques

In both quantitative and qualitative methods described above, data were collected in the manner described in the following sections. The quantitative data was collected using a structured questionnaire survey.

The qualitative data were collected as case studies of eight schools by including the following components: a historical description of the school, current enrolment and teaching staff and its academic and other activities performance record, current and proposed ICT status, a brief profile about the teacher interviewed, results of the semi-structured interviews, results of four or five students focus group and the conclusion on what these data show.

3.4.1 The structured questionnaire

The questionnaire for the quantitative phase was developed using Likert-style questionnaire items. The researcher incorporated items that were previously used by Dawson (2008) in her study titled: *Use of Information Communication Technology by Early Career Science Teachers in Western Australia*. The reason for this was that the scope of the current study was similar to Dawson's study being exploration of the usage of ICT by science teachers. Also, the questionnaire adapted some of the Technological Pedagogical and Content Knowledge (TPACK) items used by Al Harbi (2014) in her study titled: *An examination of Saudi High School Teachers' ICT knowledge and implementation*. As in Al Harbi's study, the current study involved exploring ICT knowledge and its implementation. Due permissions and proper acknowledgement of the authors of these studies was sought for use of their instruments for the data collection.

3.4.2 Draft questionnaire and piloting

Based on the Dawson (2008) and Al Harbi (2014) and discussions with experts, a draft questionnaire was prepared, and pilot tested with seven randomly selected science teachers. They were given a week's time to complete. The researcher student obtained permission from the ministry of education to conduct the piloting study in the selected schools mentioned. Feedback were obtained from these teachers on appropriateness, clarity, non-ambiguity, non-repetition and time required to complete the questionnaire and any suggestions for improvement. The feedback obtained from them was used for finalisation of the questionnaire for use in the actual survey.

3.4.3 The scales and items in the survey questionnaire

The survey questionnaire used in this research, consisted of five parts, as detailed below:

1) Part A – demographic section comprising seven items on: age, gender, teaching experience, qualification, science subject/s taught, service type, whether owns a computer with/without internet access.
2) Part B- three items on: frequency of using different types of ICT, interest in using ICT, confidence in using ICT.
3) Part C- two items on use and importance of ICT in science teaching
4) Part D- three items on factors preventing use of listed ICT resources, availability of listed ICT in schools, situation of the teacher with respect to ICT use.
5) Part E – TPACK question- one item on competence with a list of questions. TPACK will be treated in detail in Chapter 4 Results.
A blank copy of the survey questionnaire is given in Appendix C.

In all, there were 131 questions to answer. Completing the entire questionnaire should not have taken more than 30 minutes, which is reasonable. All questions had five-point rating scales from strongly no, no, neutral, yes and strongly yes types, with their wordings depending on the types of questions. There were no open-ended questions.

3.4.4 Administration of the survey

The questionnaires were posted to the selected science teachers with a pre-paid envelope using a postal service based in Bhutan. Prior approval from the Ministry of Education was obtained and concerned Dzongkhag (district) Education Officers (DEO) were informed. The participants were given the opportunity to fill in the questionnaire at their convenience, and enough time was given to complete the questionnaire so as not to affect their busy teaching schedule. The questionnaires were then collected by a colleague known to the researcher in Bhutan. Clarifications for the questionnaires were addressed through electronic and telecommunication by the researchers. The researcher was accessible to the participants for any clarifications at any time.

3.5 Case Studies

As said above, case study consisted of collecting data on a historical description of the school, current enrolment and teaching staff and its academic and other activities performance record, current and proposed ICT status, a brief profile about the teacher interviewed, results of the

semi-structured interviews, results of four or five students focus group and the conclusion on what these data show.

3.5.1 Collection of relevant information about the case schools

The relevant information about the school consisted of a historical description of the school, current enrolment and teaching staff and its academic and other activities performance record, current and proposed ICT status. These data were collected from the school as well as from the Ministry of Education, depending on the availability of the type of data.

3.5.2 Semi-structured interviews with teachers

Interview is one of the most prominent forms of qualitative data collection since it enable researchers to understand people's perceptions, meanings and situations (Punch, 2005). The interview is a flexible tool for data collection enabling multisensory channels to be used (Cohen et al., 2000, 2007). Semi-structured interviews were used for the collection of qualitative data. The interviews were conducted with eight teachers (5% of usable survey responses) in the qualitative sample and three groups of associated students. The questions for the interview included those that will seek a deeper understanding of ICT use. The main intent of the interview questions was to add more information to the quantitative data. Similar interview questions used by Al Harbi (2014) based on a framework of teacher professional ICT attributes developed by Newhouse et al. (2005) were used to frame the interview questions.

The eight teachers for interviews were selected out of the 162 teachers (usable data) who gave usable responses to the survey questionnaire and consented for the interviews. The teachers were traced back to their schools for collecting the relevant information about them as described above.

3.5.3 Piloting the interviews

A draft set of questions were pilot tested with two randomly selected teachers from survey participants. Prior to conducting interviews, the researcher obtained consent from the two selected teachers to involve them in interviews. The interviews were conducted on the school campus of each respective teacher at an agreed time. The responses from the interviews were written down in a notebook and recorded using a digital recorder. Both recordings were stored securely after the completion of interviews.

3.5.4 Description of the questions for semi-structured interviews with teachers

The list of topics for interview were framed as 18 questions. The list of topics of semi-structured interviews is given in the Appendix D.

Depending on the response to these questions, sub-questions were asked as necessary. The 18 questions dealt with purpose of using ICT, current focus on ICT use, value of students having computer, fit of ICT with current teaching methods, teacher's contribution to school planning and how the teacher would like to contribute, involvement with learners using ICT, any ICT use pattern for the teacher and how often the students use ICT either individually or in groups, strategies used for ICT, its consistency, how the strategy is determined, last term ICT activities, ICT tasks and how determined, assessment of works by students using ICT and whether it is a component of overall assessment, connecting between students' use and teacher's use of ICT, potential for ICT to support teaching and learning, students' role in deciding on the use of IC in classes. Current ICT skills and its development in future, feeling about using computer by self and students and concerns about current use of ICT and its use for teaching and learning science. Thus, in general, the interview questions were designed to evaluate what is happening in ICT use for science teaching at the implementation level, the classrooms.

3.5.5 Conducting the interviews

The interview with seven out of eight teacher participants were conducted via video conference using Facebook Messenger application. Arrangements were made to obtain a very high-quality record and to ensure that it simulated the actual face to face interview. The researcher was able to conduct a face to face interview with only one teacher and three groups of students belonging to three of the interviewed teachers. In all cases, interview time, availability, consent and approval were obtained from the participants prior to conducting the interview. The interview was recorded using Olympus digital voice recorder and file saved in a secure digital format.

The recordings were then retrieved from the recorder and transcribed into words and sentences as soon as the interview was over to ensure that no critical information was lost. Direct quotations were written down where deemed necessary and relevant. Then the record was subjected to analysis which involved interpreting the record and linking it to the main objectives of the study. This was achieved by reorganising the information, developing

connections and identifying the patterns. In the case of teacher interviews, the information obtained from the interview was divided into four main pre-categorised themes/patterns (Confidence/Skills, Use in science teaching, Importance and Resources).

The eight selected teachers, as above, participated in the semis-structured interviews. Data from the interviews were recorded in the interview sheets and were clearly written down in researcher's notebook at the time of interview. Wherever possible, the interviews were recorded using a suitable digital recorder to minimise the loss of information and maximise the reliability. Each recorded interview was audited by the participant to enhance the authenticity of the data. Excerpts from selected interviews were used to illustrate and elaborate the main themes in the final reporting. Each interview lasted 45 to 60 minutes. All interviews (teachers and students) were conducted outside normal class hours.

3.5.6 Focus group with students

For focus groups, four to five students were randomly selected from the students of three of the interviewed teachers who agreed to the conduct of interviews with their students to use it as a component of the case study on the particular school. A pilot study with a small group of students from one school was done to work out the logistics and time taken for the procedure. In total there were three focus groups.

The students of each focus group were assembled in a room and the researcher acted as the leader for conducting the focus group. The procedure given by Saunders, Lewis, and Thornhill (2009) for focus group was followed with the attendant precautions described therein.

For the students' focus groups, the information was divided into three main themes/patterns (ICT use in classroom, ICT use outside the classroom and Resources). Researcher considered these themes within the information to gain additional insights on ICT skills, ICT knowledge, ICT use and factors affecting ICT use. The responses were grouped under each of this theme based on their relationship and significance. Some of the responses were classified as belonging to two different themes due to its relevance to both the themes. After this, the number of occurrences of the themes were determined and was used to derive to a conclusion. The focus group proceedings were recorded as in the case of teacher interviews. The list of questions used in the focus group is given in the Appendix D.

3.6 Trial Analysis of Piloting Results

Trial analysis of the pilot questionnaire data involved testing for validity and reliability (Cronbach's alpha) using SPSS. The results of these analyses are described in Results chapter 4. There are many types of validity. In the case of survey data, validity refers to content validity. It answers the question: whether the survey scales and items measured what was intended to measure?

Reliability means internal consistency of the items or whether the items give reliable measurement of what it is supposed to measure and repeating the item on the same participants will produce the similar results. Cronbach's alpha is used very commonly for reliability tests. This was used in this work also. A valid method is mostly reliable also; but the reverse is not necessarily true in all cases.

The interview responses were transcribed and separated under specific themes to check whether they fulfil in supporting the questionnaire as intended. In addition, questions were checked for their consistency, accuracy, understanding and grammatical errors. Changes were made in questionnaires and interview questions wherever it was necessary, in consultation with the researcher's Supervisors. These changes were incorporated into questionnaire and interview questions to be implemented in the final phase of data collection. Overall, the trial analysis sought to analyse the data to ensure its relevance and application to comprehensively answer the research questions.

Further, to ensure that the revised questions were appropriate for the current study and context, and to minimise any ambiguities in wording, the questionnaire and interview questions were sent to selected science education officers in the Royal Education Council (REC) and Education Monitoring Division (EMD) under the Ministry of Education. In addition to these, three senior secondary science teachers were invited to fill in the questionnaires to check the clarity of questions and to check the understanding of the teachers. Similarly, the revised interview questions were piloted with two groups of students to insure understanding. Suggestions and recommendations from this pilot were incorporated into the final instrument preparation before implementation with the target samples. The finalised versions of these the teacher interview questions, and student focus group questions are given in the Appendix D and Appendix E.

3.7 Validity and Reliability

For research to be trustworthy it must be valid. Validity is a crucial key to effective research (Cohen et al., 2007). Valid research is "plausible, credible, trustworthy and defensible (Bashir, Afzal, & Azeem, 2008; Johnson, 2014). To maximise the validity and reliability of the current study, strict measures were undertaken by the researcher in various steps of the study. This included understanding the aspects of methods utilised. Care was taken in preparation of, and conduct of, interviews and questionnaires. Problems associated with interviews, such as biasing, were minimised by creating a good rapport, matching speech and behaviours with the interviewees to achieve greater validity.

Reliability and validity of the questionnaire were maximised by stressing the importance and benefits of the questionnaire to the respondents, detailing features of the questionnaire, providing encouragement through a friendly third party and understanding the nature of the sample (Cohen et al., 2007). The records of interviews were made available to the respondents for member checking to provide opportunity for respondents to correct factual errors, add additional information and to check the adequacy of the analysis to contribute to validity and reliability of the data (Cohen et al., 2007; Johnson, 2014).

The use of a mixed methods approach involving both quantitative and qualitative techniques contributed to methodological triangulation coupled with the evidence collected from multiple sources using a questionnaire, interviews and focus group discussion (data triangulation). These also lead to maximising validity and reliability of the research (Cohen et al., 2007).

3.8 Procedure

The implementation of research instruments occurred after formal approval from the Ministry of Education, Royal Government of Bhutan. After the official approval from the Ministry, the researcher corresponded with the school Principals and DEOs stating the intentions to conduct research with the teachers. The selected science teachers for the sample were also contacted and corresponded wherever possible with the aid of electronic mails and telecommunications. The participants were informed clearly regarding their participation being purely voluntarily and the responses being confidential and anonymous. Copies of questionnaires were then sent via post in a sealed envelope to the participants along with a pre-paid envelope for returning

the filled questionnaire. Based on feasibility, attempt was made by the researcher to collect the questionnaires directly from the schools.

Collection of the qualitative data from the interviews commenced after the collection and analysis of the questionnaires. The sample of selected teachers who consented for follow-up interviews were invited to participate. The researcher conducted the interviews individually to ensure in-depth exploration and understanding of the proposed research questions. The interviews were audio recorded and transcribed in an appropriate way.

Furthermore, focus group discussion with student groups were conducted from the sample randomly selected by the teacher from a class taught by the teacher participating in an interview. The focus group with students were conducted in a group of four to five members; full consent was obtained from the students and their teachers/principals to fulfil ethical considerations. The information collected was used to add to the richness of teacher interview and questionnaire data.

3.9 Data Analysis

The aim of the data analysis was to answer the following four research questions by analysing the data collected:

1. What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?

2. What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan?

3. What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms?

4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

Findings obtained from both quantitative data and qualitative data were used for answering the research questions triangulating with supporting literature in chapter 5 (Discussion chapter). Thus, parts of the data from both methods have been used for answering

the research questions. Data for quantitative and qualitative data were analysed using appropriate analysing techniques and tools. Quantitative data was analysed using SPSS and qualitative data using NVivo.

3.10 Analysis of Quantitative Survey Data

First the standard procedures were adopted for the preliminary steps of analysis including coding the data; selection of statistical measure; entering the data; cleaning and accounting for missing values; checking for outliers and normality of distribution of the data. Then, the descriptive analysis was done to estimate the main features such as means, frequencies, percentages and standard deviation.

Secondly, the data were subjected to some inferential analyses. Levene's t-test was for equivalence of population means. The Levene's t-test was used to determine whether there were any significant differences in their mean score between the male and female science teachers. This test determines whether there is statistical evidence among their associated population mean. ICT and TPACK scales were used as dependent variables and gender of the teachers was used as independent variables used for this test. The data under consideration fulfilled the criteria for conducting this test: dependent variables occur at intervals; independent variables were categorical; the samples were random, the dependent variables were approximately normal in distribution, and no significant outliers were observed. When the *p*-value was large Levene's test of equal variances assumed was applied and where the p-value was small, Levene's test of equal variances not assumed was applied. The results of this analysis are presented in section 4.6 of Chapter 4, Results.

Analysis of variance (ANOVA) was done to make comparisons. ANOVA compares the means of two or more groups to determine statistical evidence associated with the population. ANOVA was performed to determine whether there existed any significant differences in the mean scored by teachers with varied years of teaching experience. For the means to be statistically significant the p-value must be less than or equal to the significance level of 0.05. The results of this analysis are presented in section 4.7 of Results chapter.

The 22 items of the TPACK scales adopted from Al Harbi (2014) were coded and given score from 1 to 5 ("No Competence" through to "Much Competence") and the researcher used single-item score type to assign scores for each of the 22 items on this scale for each participant,

whereas, the overall score for the TPACK construct for that participant was used to determined summed scores by adding the scores of all of the 22 items.

In the case of items adapted from Dawson (2008), each item was coded and given score from 1 to 4 and calculated the Mean and Standard Deviation for each item separately. Similarly, the items from ICT Skills Scales were coded 1 to 4 and the means calculated across the all the items.

The qualitative data was subjected to a proper method of analysis. Available software such as *NVivo* was utilised to analyse the data from interviews. Analysis of qualitative data basically involved coding and categorising into themes from teachers' and student groups' interview transcripts and reporting the details of patterns in the results. The method adopted by Judger (2016) using Braun and Clarke (2006) for thematic analysis in NVivo software was used here. The reasons for using thematic analysis were that it is the most commonly used analytical method for interview data, the conceptual aspects of Braun & Clark's method matched with the conceptual aspects of the interviews in this research as it identifies, analyses and reports on patterns (themes) within the interview data. The rigorous thematic approach can give an insightful analysis which can be used for answering certain aspects of the research questions as is explained in Chapter 5 Discussions. Most of the research questions raised above were answered from the themes identified by this method of analysis.

3.11 Ethical Considerations

Ethics approval from Edith Cowan University was obtained before the commencement of the study as prescribed under the University rules of Research Ethics and Integrity. In addition, ethics approval from the Ministry of Education, Bhutan was also obtained before conducting this study. The participants had to give consent after being informed about the essentials of the project. So, informed consent was ensured. The privacy of information on their personal details and confidentiality regarding the participation and information collected from them were guaranteed before the collection of data. Also, the participation was based purely on voluntary basis. No sensitive information other than the required information were collected from the participants and the researcher ensured that there were no potential physical, psychological, social or legal risks to the participants. The researcher was aware that his position as an Education Officer working in the Headquarters might jeopardise the collection of data. This issue was taken care of by the voluntary nature of their participation and freedom to withdraw

from participation without assigning any specific reason. All data collected were stored and were expected to be destroyed five years from the completion of this study. The electronic data were stored in the researcher's laptop with pass-word protection limiting access only to the researcher. All possible steps were taken to prevent malicious attacks and loss of data from the computer by updating the security system as frequently as available and not downloading suspicious or unwanted materials. Backups of these electronic data and hard copies of raw, under process and processed data were kept in a safe and the keys were kept only by the researcher. None other than the researcher handled any material connected with this research stored in the computer or in the safe.

3.12 Summary

The mixed methods research with explanatory sequential design that used both quantitative and qualitative data was expected to achieve the objectives and the propositions of the study. The design was expected to provide valuable data to understand the pattern of ICT use by science teachers in middle secondary schools in the Kingdom of Bhutan. Meaningful results leading to some useful conclusions were made possible by following proper measures and techniques of data collection and analysis described in this chapter. Ethical procedures were strictly followed, and validity and reliability of the data was ensured throughout the conduct of the study.

CHAPTER 4: QUANTITATIVE ANALYSIS

To address the main research questions for this study, a mixed methods approach was utilised involving both quantitative and qualitative process. A questionnaire was used as the quantitative tool. From 63 schools, 189 teachers were randomly selected and were sent survey questionnaire. Out of this 189, usable response was obtained from 162 teachers giving a response rate of 85.7%. The data gathered from the questionnaires were analysed using *IBM SPSS Statistic Version 24.*

This chapter presents of the quantitative analysis of data collected using questionnaires. The chapter is divided into four parts: (1) Demographic information; (2) Descriptive Statistics on items; (3) Analysis of Scales, and (4) Quantitative results.

4.1 Demographic Information

Out of 63 middle secondary schools with 189 science teachers, a total of 162 science teachers that constituted 46 middle secondary schools across the country completed the questionnaire during the second half of the school academic year in 2016. The demographic details of the respondents from the survey are described below.

4.1.1 Respondents' age group

Of the total 161 respondents who responded to this question, 46% of them were between the age of 30-39 years followed by respondents in the age group of 25-29 years comprising 25%, and the age group 40-49 years with 20%. Thus, majority of the survey participants (92%) were in the age group of 25 to 49 years. These data are presented in Table 4.1.

Table 4. 1

Age of respondents

Age range	Frequency	Percent
Under 25 Years	5	3
25-29 Years	40	25
30-39 Years	75	46
40-49 Years	33	20
Above 50 Years	8	5

4.1.2 Gender

Male teachers were in majority (68%) compared to female teachers (32%) among the survey participants. The number of male teachers was more than double the number of female teachers.

4.1.3 Teaching experience

The data presented in Table 4.2 shows that most teacher respondents had a teaching experience of 6 to 10 years (33%), followed by teachers with 11 to 20 years of teaching experience (29%). Recently graduated teachers with less than 5 years of teaching experience consisted 26% of respondents while the number of teachers with greater than 20 years consisted only (11%). The result indicated that science education in middle secondary schools were mostly (73%) handled by teachers with adequate teaching experiences of at least five years or more.

Table 4. 2

Teaching experience of the respondents

Age range	Frequency	Percent
Less than 5 Years	43	27
6-10 Years	54	33
11-20 Years	47	29
More than 20 Years	17	11

4.1.4 Qualifications

According to the data given in Table 4.3, almost half of the respondents (47%) had a Bachelor's in Education (B.Ed.) as their qualification, followed by teachers (30%) with Post-graduate qualification (PGCE/PGDE). Teachers with a master's degree comprised (20%) of the total sample while a lone teacher from the respondents had a Primary teaching qualification (PTC). There were two teachers with a Doctorate level qualification (PhD). The result showed that the most of the middle secondary science teachers had adequate qualifications (Bachelors and Postgraduate) in science as well as teaching methods.

Table 4. 3

Qualifications of the respondents

Qualification	Frequency	Percent
PTC	1	1
B.Ed.	76	47
PGCE/PGDE	49	30
Master's	32	20
PhD	2	1

4.1.5 Science subjects taught

The distribution of teachers for teaching the middle secondary science subjects is shown in Table 4.4. Out of the total sample, 71 teachers taught Biology as the main subject, 65 taught Chemistry and 53 teachers were Physics teachers. Some of these teachers taught more than one science subjects. A typical middle secondary science teacher would teach a combination of two subjects, usually a combination of Biology and Chemistry or Chemistry and Physics. It revealed from the data that number of Biology teachers outnumbered those teaching Chemistry and Physics.

Table 4. 4

Science subjects taught

Science subjects taught	Number of respondents
Biology	71
Chemistry	65
Physics	53

4.1.6 Types of employment

According to the data given in Table 4.5, the highest number of respondents (90%) had a regular fixed employment in civil service under the Government of Bhutan while the expatriate and teachers on contract consisted of (8%) and (2%) respectively. This result was a positive indication of gaining self-sufficiency in terms of teacher employment from within the country and not having to depend on outside source for teachers. Since the introduction of modern form of education in 1960, Bhutan had been heavily relying on expatriate teachers especially from

India, but with changing times coupled with sound government policies, the dependency has reduced, and schools were now managed by qualified Bhutanese teachers.

Table 4. 5

Employment types

Employment types	Frequency	Percent
Regular	146	90
Expatriate	13	8
Temporary/Contract	3	2

4.1.7 Owning a computer with Internet access

The analysis on science teachers owing a computer with internet access (Fig 4.1) showed that majority of the middle secondary science teachers (68%) possessed a computer with Internet access. Twenty three percent of the teachers still owned a computer though without an Internet access and only a small number of teachers (9%) had no computer as their possession. This result supported the initiatives undertaken by the government to empower teachers with ICT skills through program such as the Chiphen Rigphel and the positive environment available for Bhutanese teachers to use these ICT tools. Thus, majority of teachers had access to Internet although there were also teachers who had no access to Internet even though they had their own computer.

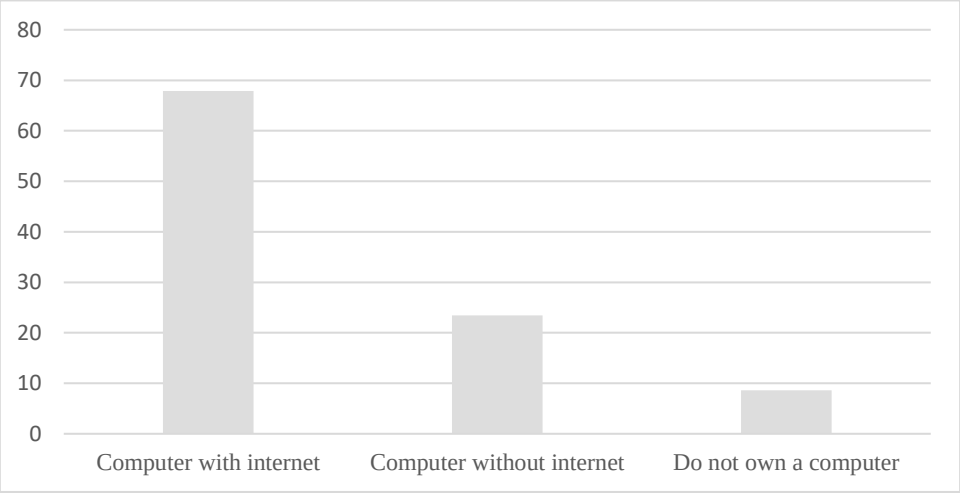


Figure 4. 1. Owning a computer

4.2 Descriptive Statistics on Items Forming the Scales

This section contains descriptions on the type of ICT items (tools) used by the teachers in their personal life, their level of interest in using ICT, their level of confidence to use ICT, their use of ICT in science teaching, their views on the importance of ICT in science teaching and the TPACK. Six scales were obtained from the different items that were used in the questionnaire. These scales were: (i) Use of ICT in daily life (ii); Interest to use ICT (iii); Level of confidence to use ICT (iv); Use of ICT in science teaching (v); Importance of ICT, and (vi). TPACK scale. 13 items formed the scale for ICT related scales (Scale i to v) while 22 items formed the scale on TPACK. Prior to conducting the analysis, the data was coded and entered in Microsoft Excel from where it was exported to SPSS for further analysis.

The following sections report on the descriptive statistics analysis for the items that comprised the scales.

4.2.1 Use of ICT in daily life by science teachers

This section reports on items that comprised the scale "Use of ICT in daily life". Responses to items for use of ICT in daily life was measured using Likert scale that ranged from 1 (*Never*) to 4 (*Always*). The mean and the standard deviation (SD) for each ICT items is summarised in Table 4.6 ranked from highest to lowest mean. The results revealed that the mean for most of the ICT use was very high indicating a frequent use of ICT by science teachers in their daily life. Most of them frequently used: Mobile phones; Internet; Social Networking; Word processing and Email communication, with a mean of 3.00 to 4.00. The ICT that were used rarely by the science teachers were: Web designing; E-journals, and Databases with a mean of less than 2.00. The standard deviation for all items were less than 1.00, except for one item (Digital Camera), indicating the general pattern of ICT use by teachers in their daily life described by their mean value. The results indicated that technological gadgets such as mobile phones are readily available for teachers and other ICT items such as Internet and Word processing are also becoming easily accessible to them for use in their day to day life. These results indicate the level of familiarity with technology and tools for their uses, which the teachers may use in teaching also.

Table 4. 6

ICT use by science teachers in their daily life (n=162)

ICT Use	Mean	SD
Mobile phones with Internet access	3.87	0.51
Internet Browsing	3.76	0.50
Social networking (e.g. Face book)	3.62	0.78
Word processing (e.g. MS Word)	3.44	0.75
Email Communication	3.01	0.83
Printer	2.80	0.82
Spread sheet (e.g. Excel)	2.65	0.89
Slideshow (PowerPoint)	2.64	0.82
Data Projector	2.28	0.80
Digital Camera	2.06	1.08
Databases	1.69	0.96
E-journals	1.64	0.91
Web designing	1.15	0.51

4.2.2 Interest to use ICT by science teachers

This section reports on items that formed the scale "Interest to use ICT". Responses to items for the interest to use ICT by science teachers were measured using Likert scale ranging from 1 (*Not Interested*) to 4 (*Very Interested*). The mean and standard deviation for each ICT tool used is summarised in Table 4.7 ranked from highest to lowest mean. Overall, majority of science teachers have expressed a very high level of interest to use the ICT. Internet browsing with a mean of 3.69 topped the interest lists for science teachers followed by Mobile phones, Word processing and Social Networking. From the 13 items, there were only three items with mean less than 3.00, rest of the 10 items were found to have the mean above 3.00 representing "Interested" to use ICT. The lowest mean was for Web designing with a mean of 2.52 representing "Somewhat Interested" which still showed some interest.

The results indicated the ever-growing dependence on Internet and its popularity. Further, it also indicated the strong influence asserted by the modern electronic gadgets such as smartphones and increasing use of social networking in everyday communications. On the negative side, it also showed that science teachers were lacking skills and knowledge in areas

such as accessing the online journals, databases and creating online learning platforms like webpages. Knowledge in these aspects is essential to use technology in science education.

Table 4. 7

Interest to use ICT by science teachers (n=162)

ICT Use	Mean	SD
Internet Browsing	3.69	0.52
Mobile phones with Internet access	3.64	0.56
Word processing (e.g. MS Word)	3.47	0.58
Social networking (e.g. Face book)	3.40	0.70
Slideshow (PowerPoint)	3.35	0.64
Email Communication	3.28	0.69
Spread sheet (e.g. Excel)	3.25	0.66
Printer	3.22	0.64
Data Projector	3.17	0.75
Digital Camera	3.14	0.80
Databases	2.71	0.94
E-journals	2.69	0.89
Web designing	2.52	1.04

4.2.3 Level of confidence to use ICT by science teachers

This section reports on the items that formed the scale "Level of confidence to use ICT". Teachers' responses for the level of confidence to use ICT was measured with Likert scale that ranged from 1 (*Not Confident*) to 4 (*Very Confident*). The mean and the standard deviation is presented in table 4.8 ranked in descending order. The highest mean was observed for the use of: Mobile phones (3.49) and Social networking (3.41); followed by Internet use; Word processing; Slideshow, and Email communication. Out of the 13 items, the mean for seven items were more than 3.00 that represented "Confident", three items had mean less than 3.00 but more than 2.00 that represented "Somewhat Confident", whilst other three items had mean less than 2.00 representing "Not Confident" on the scale. Items with mean less than 2.00 were: E-journals; Databases, and Web designing. The results indicated that in general, science teachers exhibited high confidence in commonly used ICT items such as: Mobile phones; Social networking, and Internet, but they lacked confidence in areas of ICT that were used least

or not available for them to use such: as Spread sheet; Data projectors, and Digital cameras. Their confidence level to use ICT could be related to their perceptions, attitudes, skills and knowledge of ICT.

Table 4. 8

Science teachers' confidence level to use ICT (n=162)

ICT Use	Mean	SD
Mobile phones with Internet access	3.49	0.68
Social networking (e.g., Face book)	3.41	0.70
Internet Browsing	3.37	0.74
Word processing (e.g., MS Word)	3.36	0.72
Slideshow (PowerPoint)	3.26	0.74
Email Communication	3.24	0.77
Printer	3.01	0.79
Spread sheet (e.g., Excel)	2.94	0.90
Digital Camera	2.74	0.97
Data Projector	2.67	0.91
E-journals	1.99	0.94
Databases	1.79	0.93
Web designing	1.30	0.71

4.2.4 Use of ICT in science teaching by science teachers

This section reports on the items that comprised the scale "Use of ICT in science teaching". Responses to items concerning the use of ICT by science teachers in science teaching ranged from 1 (*Never*) to 4 (*Daily*). The mean and standard deviation is shown in Table 4.9 ranked from highest to lowest. Out of 13 items the mean for two items were more than 3.00 representing the use "once in a week", the mean for seven items were between 2.00 and 3.00 representing "once in a month" while the mean for other four items were less than 2.00 that represented "Never" on the scale. The items with the highest mean were: Mobile phones and Internet with a mean of 3.28 and 3.27 respectively; followed by Word processing (2.97), and Printer (2.65). The least used ICT were: Web designing (1.14); Databases (1.46); E-journals (1.53), and Digital cameras (1.88). While the Mobile phones usage was high, the standard deviation for it was found to be greater than 1.00 indicating a varied use. The possible reasons

could be their lack of knowledge and skill on how to use them for science teaching and probably lack of a proper platform in the teaching system to accommodate this ICT item. Similarly, ICT such as Email communication was not used more frequently in teaching, although the teachers' interest level and confidence level were very high for this item, and it was also most extensively used in their daily life. This also explains the lack of knowledge and skills on how to use these for online communications in discussion forums between the teachers and students and among students.

Table 4. 9

Use of ICT by science teachers in science teaching (n=162)

ICT Use	**Mean**	**SD**
Mobile phones with Internet access	3.28	1.01
Internet Browsing	3.27	0.77
Word processing (e.g. MS Word)	2.97	0.85
Printer	2.65	0.80
Slideshow (PowerPoint)	2.61	0.81
Social networking (e.g. Face book)	2.60	1.22
Spread sheet (e.g. Excel)	2.34	0.91
Data Projector	2.27	0.79
Email Communication	2.21	0.97
Digital Camera	1.88	0.98
E-journals	1.53	0.77
Databases	1.46	0.77
Web designing	1.14	0.50

4.2.5 Importance of ICT in science teaching

This section reports on the items that formed the scale "Importance of ICT in science". Teachers' responses for the importance of ICT in science teaching was ranged from 1 (*Not Important*) to 4 (*very Important*). The mean and standard deviation for the importance of ICT is shown in Table 4.10 ranked from highest to lowest. Seven items had mean above 3.00 representing "Important" and rest of the other items had mean less than 3.00 but more than 2.00 that represented "Moderately Important". The item with the highest mean was for Internet

with 3.88 which was very close to 4.00 (Very Important). The lowest mean was for web designing with 2.03.

In general, science teachers felt that all the ICT items presented were important in science teaching as indicated from the mean score (the lowest mean=2.03). Their perceptions as how important it is to use ICT in science teaching closely related to how often they used, their interest and the confidence level. While the results showed positive attitudes towards importance of ICT in teaching, there were also certain indications of teachers having inadequate knowledge in terms of potentiality of ICT use such as: Social networking; Web designing; Databases; E-journals, and Digital cameras, as the standard deviation for these items were very high. The possible reasons for these results could be due to lack of resources and knowledge to implement these ICT items in their teaching.

Table 4. 10

Importance of ICT in science teaching (n=162)

ICT Use	**Mean**	**SD**
Internet Browsing	3.88	0.33
Mobile phones with Internet access	3.55	0.72
Slideshow (PowerPoint)	3.54	0.62
Word processing (e.g., MS Word)	3.43	0.70
Data Projector	3.42	0.70
Printer	3.31	0.74
Spread sheet (e.g., Excel)	3.11	0.85
Email Communication	2.94	0.79
Digital Camera	2.88	0.84
E-journals	2.68	0.92
Social networking (e.g., Face book)	2.67	0.92
Databases	2.54	0.94
Web designing	2.03	1.04

4.2.6 Items for TPACK scale

This section describes the items that formed the scale "TPACK". Teachers' responses to TPACK competence were based on their responses to 22 items in the questionnaires. These items were ranged from 1 *(No Competence),* 2 *(Little Competence),* 3 *(Not Sure),* 4 *(Moderate*

Competence) and 5 *(Much Competence).* The mean and standard deviation for the TPACK items is presented in Table 4.11 ranked from the highest to the lowest. The mean for 20 items were found to be more than 3.00 and only two items had mean less than 3.00 but were more than the mid-point mean value (2.50). A mean of more than 3.00 represented "Moderate Competence" meaning "Competent", whilst a mean of less than 3.00 represented "Little Competence" meaning "Less Competent".

Referring to items lists on Appendix C Part E, the highest mean was for item 13 *(I can use technology to update my knowledge and skills in the area that I will teach)* with a mean value of 4.23, followed by item 4 *(I can plan the teaching and learning process according to available technological resources)* with a mean value of 4.06 and item 14 *(I can update my technological knowledge for the teaching process)* with a mean value of 4.02. The least mean score was for item 19 *(I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process)* with a mean value of 2.72. Although the mean value was less than the rest of the items, the value still indicated some competence. The standard deviation for 19 of the items was more than 1.00 suggesting the responses deviated much from the mean. This could also have indicated that the TPACK differ from one teacher to another teacher.

Table 4. 11

Rank wise mean for TPACK items (n=162)

Items	Mean	SD
I can use technology to update my knowledge and skills in the area that I will teach.	4.23	0.85
I can plan the teaching and learning process according to available technological resources.	4.06	0.89
I can update my technological knowledge for the teaching process.	4.02	0.97
I can develop appropriate assessment tools by using technology.	3.88	1.01
I can use technology to develop activities based on student needs to enrich the teaching and learning process.	3.85	1.05
I can use technology for implementing educational activities such as homework, projects, etc.	3.80	1.06
I can use technology to determine students' needs related to a content area in the pre-teaching process	3.79	1.08
I can implement effective classroom management in the teaching and learning process in which technology is used	3.78	1.00

I can update an instructional material (paper based, electronic or multimedia materials, etc.) based on the needs (students, environment, duration, etc.) by using technology.	3.62	1.09
I can behave ethically regarding the appropriate use of technology in educational environments.	3.55	1.23
I can apply instructional approaches and methods appropriate to individual differences with the help of technology.	3.48	1.04
I can use technology-based communication tools (blog, forum, chat, e-mail, etc.) in the teaching process.	3.47	1.16
I can assess whether students have the appropriate content knowledge by using technology.	3.44	1.10
I can be an appropriate model for the students in following codes of ethics for the use of technology in my teaching.	3.43	1.14
I can use technology in every phase of the teaching and learning process by considering the copyright issues (e.g. license)	3.38	1.14
I can use technology to find solutions to problems (structuring, updating and relating the content to real life, etc.).	3.29	1.27
I can use innovative technologies (Facebook, blogs, twitter, podcasting, etc.) to support the teaching and learning process.	3.28	1.26
I can cooperate with other disciplines regarding the use of technology to solve problems encountered in the process of presenting content.	3.27	1.27
I can provide guidance to students by leading them to valid and reliable digital sources.	3.22	1.26
I can follow the teaching profession's codes of ethics in online educational environments (Web CT, Moodle, etc.).	3.01	1.19
I can become a leader in spreading the use of technological innovations in my future teaching community.	2.94	1.23
I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process	2.72	1.22

4.3 Analysis of Scales

This section reports on analysis of the six scales: (i). Use of ICT in daily life (ii). Interest to use ICT (iii). Level of confidence to use ICT (iv). Use of ICT in science teaching (v). Importance of ICT in science teaching, and (vi). TPACK scale.

4.3.1 Preliminary data analysis

Prior to scale analysis, the data were subjected to preliminary processing and tests which included checking for any missing values, checking for outliers, checking for normality and conducting reliability tests. The following sub-section describes these processes in detail.

4.3.2 Checking for missing values

Missing values occurs when the respondents do not provide response to a whole question or to a part of a question. It is stated to be one of the most important statistical problems in quantitative research studies (Acock, 2005). Missing values can lead to invalid conclusions and can have huge effect on results.

There exist several ways for researchers to deal with this issue of missing value. To deal with the missing values, a researcher must assume that the data is either Missing Completely at Random (MCAR), Missing at Random (MAR) or Missing Not at Random (MNAR). Based on the type of data assumed then the researcher can replace the missing values by using various methods. Some of these methods include *list wise deletion; pairwise deletion; mean substitution* or *Expectation Maximisation* (EM). Techniques such as EM are more recent ones and are supposed to be more powerful as compared to other techniques. There is also an option for a user to give command to SPSS for missing values. When this is done, SPSS generates a result omitting the missing values. For this current study, the missing values were coded as "99" in SPSS and data was assumed to be MCAR. Little's (1988) Missing Completely at Random test was performed to confirm that the data was MCAR. All the scales were found to be MCAR (p value greater than 0.05) except for the scale that measured interest to use ICT. MCAR test is shown in Table 4.12. The percentage of missing data was found to be 1.73% as shown in Figure 4.2 which was not very high.

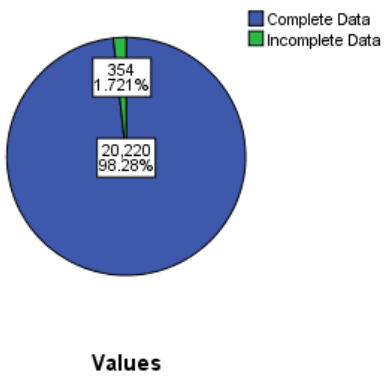


Figure 4. 2. Overall summary of missing value

Table 4. 12

Little's MCAR test

Scale Type/Variables	Number of items	Little's MCAR test
Use of ICT in daily life	13	0.226
Interest to use ICT	13	0.001
Level of confidence to use ICT	13	0.856
Use of ICT in science teaching	13	0.151
Importance of ICT in science teaching	13	0.333
TPACK	22	0.006

4.3.3 Checking for outliers

An outlier is an observation that lies an abnormal distance from other values in a random sample from a population. Outliers should be investigated carefully since it significantly affects mean and standard deviation of a distribution. Often, they contain valuable information about the process under investigation or the data gathering and recording process. Before considering the possible elimination of these points from the data, one should try to understand why they appeared and whether it is likely similar values will continue to appear. For the present study, outliers were checked first by visually inspecting the distribution of histograms and box plot (Figure 4.3 to 4.8). SPSS was used to generate histograms and box plot for the main variables to see for any extreme cases then, the scores were converted to standardised scores to confirm the existence of significant outliers. For all the variables, the Z-score was found to be within the acceptable range of -4.00 to +4.00 showing the absence of any significant outliers. (Table 4.13)

Table 4. 13

Standardised scores for the variables (Z-Score)

Z-score	N	Minimum	Maximum
Z-score (ICT Daily Use)	162	-3.01	3.26
Z-score (ICT Interest)	162	-3.17	1.67
Z-score (ICT Confidence)	161	-3.13	2.14
Z-score (ICT Use Teaching)	162	-2.61	2.97
Z-score (ICT Importance)	161	-2.66	1.87

Z-score (TPACK Score Sum)	162	-2.93	1.79
Valid N (list wise)	162		

4.3.4 Checking for normality

To validate the normal distribution of variables, normality test was done on both the dependent variables and the independent variables. Both graphical and statistical approaches were used to determine the normality. Graphical approach involved inspecting the frequency histograms and expected normal probability plot of the variables while the statistical approach involved obtaining the Skewness and Kurtosis values. As shown in the Figures 4.3 to 4.8, the scores appeared to be reasonably distributed. The absolute values of Skewness and Kurtosis was found to be less than 1.00 suggesting that the data were approximately normal. (Table 4.14).

Table 4. 14

Skewness and Kurtosis values

Scale Type/Variables	Skewness	Kurtosis
Use of ICT in daily life	0.36	0.57
Interest to use ICT	-0.60	-0.46
Level of confidence to use ICT	-0.24	0.86
Use of ICT in science teaching	0.05	0.009
Importance of ICT in science	-0.06	-0.51
TPACK	-0.35	-0.36

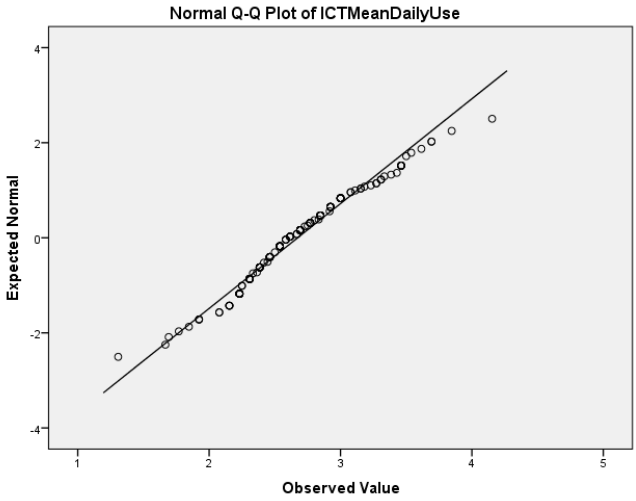


Figure 4. 3. Expected normal probability plot for daily use of ICT

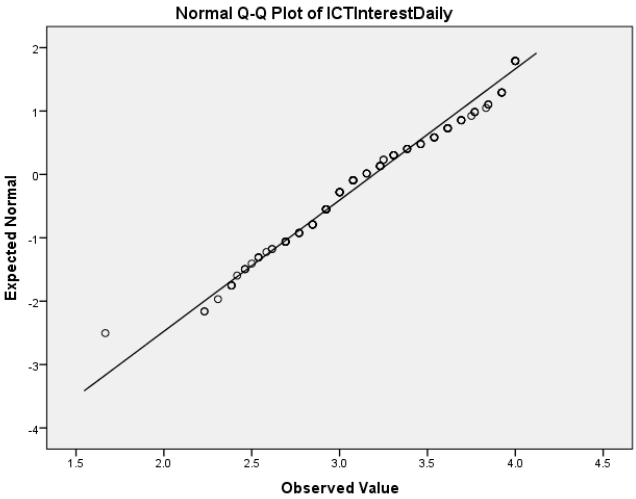


Figure 4. 4. Expected normal probability plot for interest to use ICT

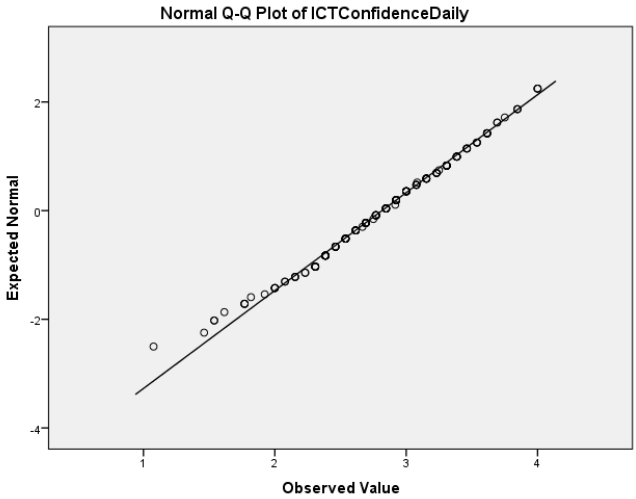


Figure 4. 5. Expected normal probability plot for confidence to use ICT

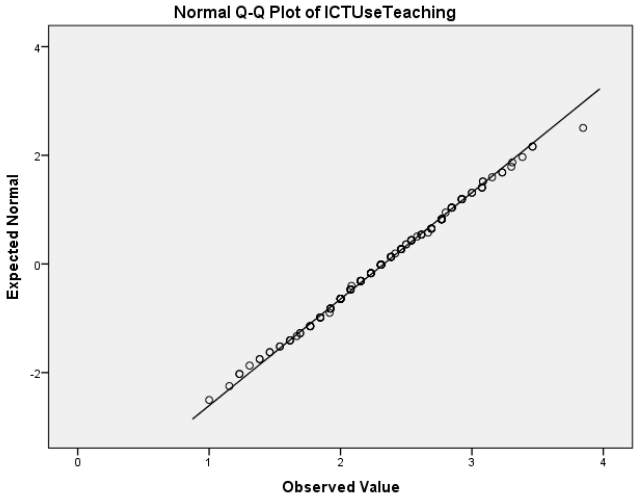


Figure 4. 6. Expected normal probability plot for use of ICT in science teaching

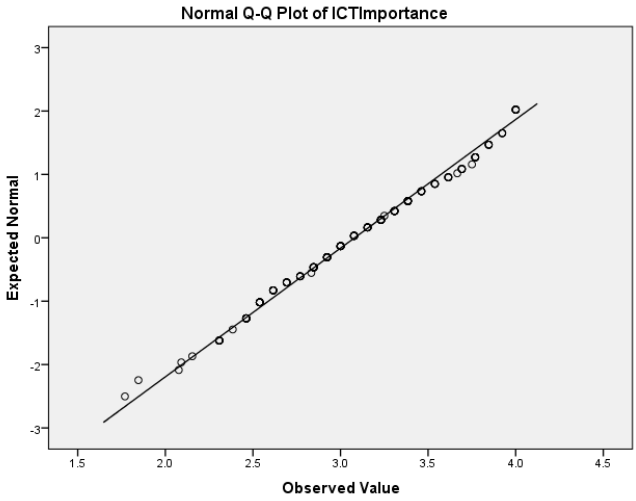


Figure 4. 7. Expected normal probability plot for importance to use ICT

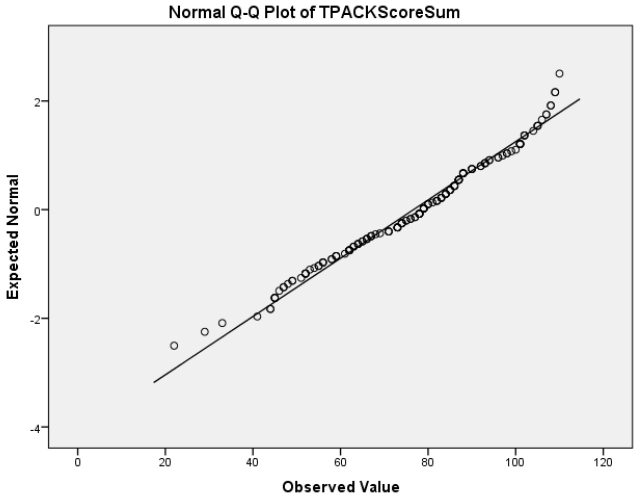


Figure 4. 8. Expected normal probability plot for TPACK

4.3.5 Reliability tests

Reliability determines how consistently an instrument measures what it is purported to measure. It is essential to use a valid and reliable instrument when collecting any data in research (Gay et al., 2009). The reliability for the items were assessed using Cronbach's alpha. Using SPSS, items were subjected to reliability test and Cronbach's alpha determined as shown in Table 4.15. A reliability coefficient of 0.70 or higher is considered acceptable for the instrument to be reliable and consistent. The Cronbach's alpha for all items tested were greater than 0.80 suggesting that the items have high internal consistency.

Table 4. 15

Reliability test

Scale Type/Variables	Number of items	Cronbach's Alpha
Use of ICT in daily life	13	0.83
Interest to use ICT	13	0.88
Level of confidence to use ICT	13	0.90
Use of ICT in science teaching	13	0.84
Importance of ICT in science	13	0.86
TPACK	22	0.96

4.4 Descriptive Statistics for Scales (Quantitative Results)

As mentioned in section 4.3, a total of six scales were derived from the items. This section reports on the analysis of the descriptive statistics for these six scales. These descriptive statistics are shown in Table 4.16. These results for each scale are then discussed separately.

Table 4. 16

Min, Max, Mean, Median and SD for Scales

Scales	Min	Max	Mean	Median	SD
Use of ICT in daily life	1.31	4.00	2.67	2.61	0.45
Interest to use ICT	1.67	4.00	3.20	3.15	0.48
Level of confidence to use ICT	1.08	4.00	2.82	2.84	0.55
Use of ICT in science teaching	1.00	3.85	2.33	2.30	0.51
Importance of ICT in science	1.77	4.00	3.08	3.07	0.49
TPACK (sum of item scores)	22.00	110.00	76.66	79.0	18.63

4.4.1 Scale: Use of ICT in daily life

The reliability test for this scale was found to be high with a Cronbach's alpha of 0.83 confirming that the scale used was reliable and items had high degree of internal consistency. The items that formed this scale were ranked from 1 to 4 (1=" Never", 2=" Rarely or Once a Month", 3=" Frequently or Once a Week" and 4=" Always"). The mean value for this scale was 2.67 representing a use of ICT "Rarely or Once a Month", which was more than the mid-point of 2.5 for the scale. The maximum and minimum scores for the items were 1.31 and 4.00 respectively with a SD value of 0.45. The low standard deviation indicated that all the responses were close to the mean. From the mean value (2.67) it can be interpreted that most of the teachers used ICT in their daily life at least once a month to weekly. The median value of 2.61 was close to the mean, which further supported this ICT use pattern in their daily life.

Responses for this scale was checked for any missing value and was subjected to Little's test to determine whether the data were MCAR. The Little test value was 0.226 indicating that it was MCAR. No outliers were detected and the standard z score for all variables were within the acceptable range of -4.00 to +4.00. The normality of distribution of data was determined by plotting a histogram (Figure 4.9) and calculating the Skewness and Kurtosis value. The Skewness and Kurtosis value were less than 1.00 indicating that the data were approximately normal. (Table 4.14)

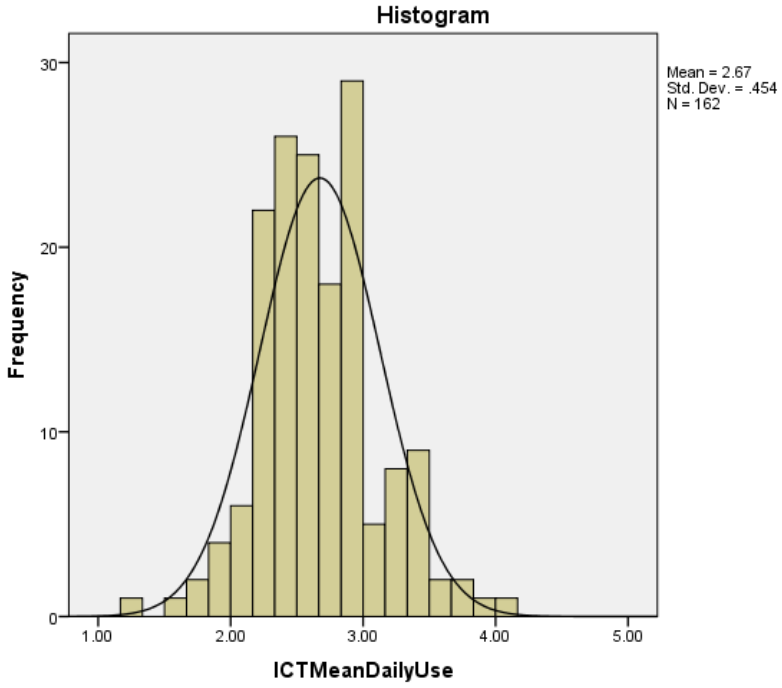


Figure 4. 9. Distribution of variables for use of ICT in daily life

4.4.2 Scale: Interest to use ICT

The Cronbach's alpha for this scale was 0.88 which confirmed that the data were reliable and consistent. The items that formed this scale were ranked from 1 to 4 (1=" Not Interested", 2=" Somewhat Interested", 3=" Interested", 4=" Very Interested"). The mean value for this scale was 3.20 which was almost close to the maximum mean value of 4.00. The median value was close to the mean with 3.15. The maximum score for the item was 4.00 and the minimum score was 1.00. The SD value was 0.48, which was less than 1.00 indicating that the responses were closer to the mean. The high mean value (3.20) indicated that all the teacher respondents were "Interested" to use ICT.

For this scale, Little's test was rejected as the value for Little's test was less than 0.05. However, no significant outliers were found and the standard z-score for all variables were within the acceptable range of -4.00 to +4.00. The normality of distribution of data was determined by plotting a histogram (Figure 4.10) and calculating the Skewness and Kurtosis value. The Skewness and Kurtosis value was less than 1.00 (Table 4.14) indicating that the data were normally distributed.

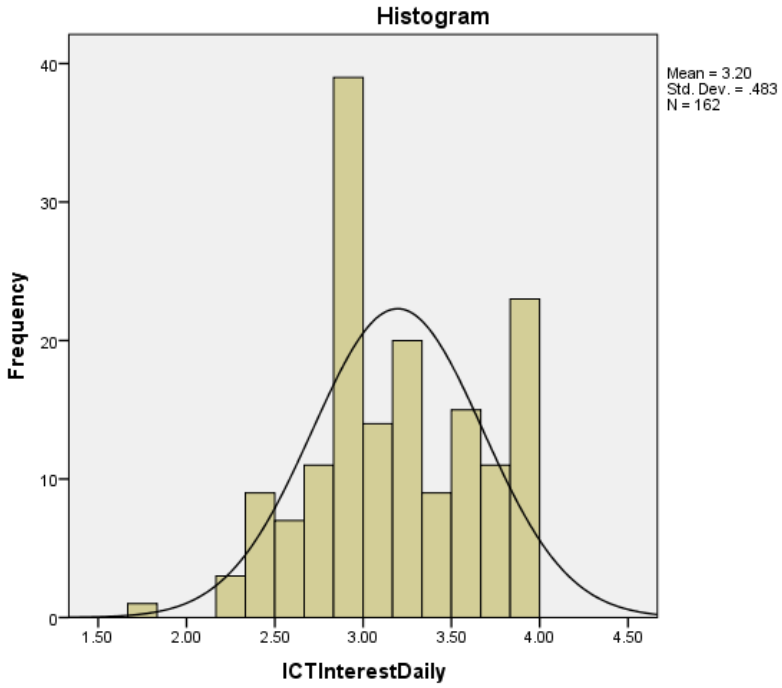


Figure 4. 10. Distribution of variables for interest to use ICT

4.4.3 Scale: Level of confidence to use ICT

The reliability test for this scale showed a very high Cronbach's alpha of 0.90. This high value of Cronbach's alpha suggested that the scale was reliable and consistent. The items for this scale were ranked from 1 to 4 (1=" Not Confident", 2=" Somewhat Confident", 3=" Confident", 4=" Very Confident"). The mean value for this scale was 2.82 which was more than the mid-point value of 2.5. The maximum score for the item was 4.00 and the minimum score was 1.08 with a SD value of 0.55. The SD value was less than 1.00 showing that the responses were closer to the mean. From the mean value (2.82) and the median value 2.84, it can be interpreted that most of the teachers were "Confident" to use the available ICT present in the schools.

Little's test for this scale showed that the data for this scale were MCAR (Little's test 0.856). The Z-score was found to be within the acceptable range of -4.00 to +4.00 showing the absence of any significant outliers. The value for Skewness and Kurtosis were less than 1.00 (Table 4.14) and visual inspection of normal probability and histogram plot (Figure 4.11) showed that the data were approximately normal.

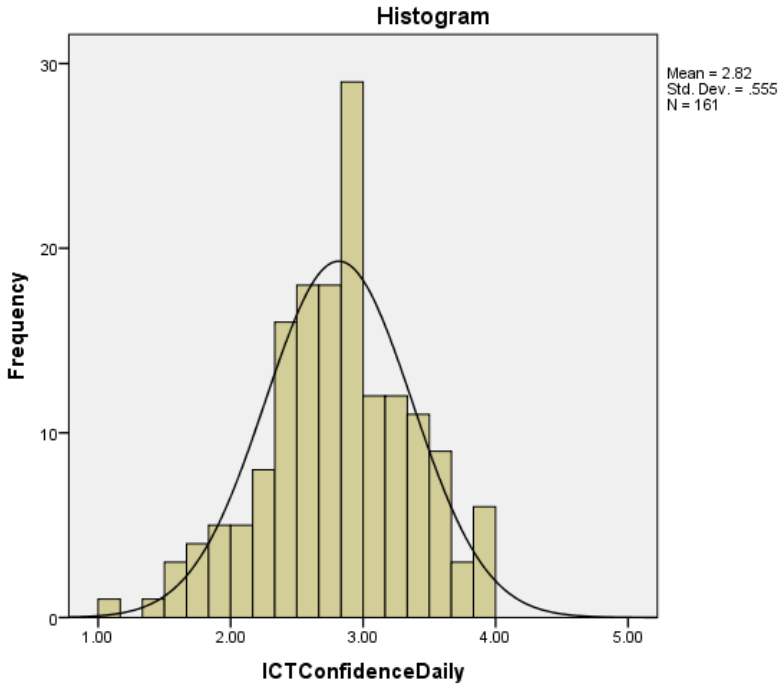


Figure 4. 11. Distribution of variables for level of confidence to use ICT

4.4.4 Scale: Use of ICT in science teaching

The Cronbach's alpha for this scale was 0.84 confirming the reliability of the data. The mean value for this scale was found to be the least compared to other scales. The items for this scale were ranked from 1 to 4 (1=" Never", 2=" Once in a month", 3=" Once in a week", 4=" Daily"). The mean value was found to be 2.33 representing use of ICT "Once in a Month" and the median value 2.30. The maximum and minimum scores for items were 3.85 and 1.00 respectively. The SD was 0.51 suggesting that the responses were closer to the mean. From the mean value (2.33) it can be assumed that most of the teachers used ICT in science teaching "Once in a Month" and a fewer teachers used ICT "Once in a Week". The maximum score for the item was 3.85 indicating that there were variations of ICT use in science teaching among the teachers. It is probable that while some teachers used ICT extensively in their teaching there were also those who do not use them very often.

The data for this scale was MCAR with the Little's test value of 0.151. There were no significant outliers and the Z score for all the variables were with the acceptable range of -4.00 to +4.00. The Skewness and Kurtosis values were less than 1.00 (Table 4.14). The visual inspection of histogram (Figure 4.12) showed that data were normal.

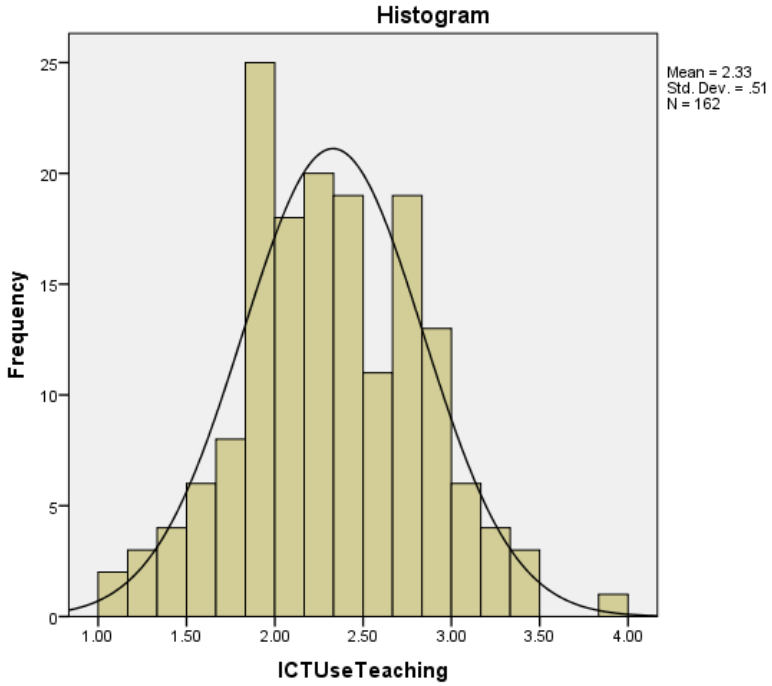


Figure 4. 12. Distribution of variables for use of ICT in science teaching

4.4.5 Scale: Importance of ICT in science teaching

The reliability test for this scale showed a Cronbach's alpha of 0.86 that confirmed the data were reliable and consistent. The items for this scale was ranged from 1 to 4. (1=" Not Important", 2=Moderately Important", 3=" Important", 4=" Very Important"). The mean value for this scale was the highest among the six scales. The mean value was found to be 3.08 representing "Important" and the median value 3.07. The maximum and minimum scores for the items were 4.00 and 1.77 respectively with SD value of 0.49. A very low SD showed that the responses were very close to the mean and the importance given to ICT use in science teaching by teachers was highly significant. The results suggested that majority of teachers considered ICT use in science teaching to be "Important". This is essential since the perception of teachers towards use of ICT is highly relevant to how much they would use in their teaching.

The data for this scale were considered MCAR since it fulfilled Little's test (0.333). No significant outliers were detected and if any were within the acceptable range of -4.00 to +4.00. The normality test showed that the data were approximately normal with Skewness and Kurtosis value less than 1.00. (Table 4.14) Furthermore, visual inspection of the histogram (Figure 4.13) supported that the data were normal.

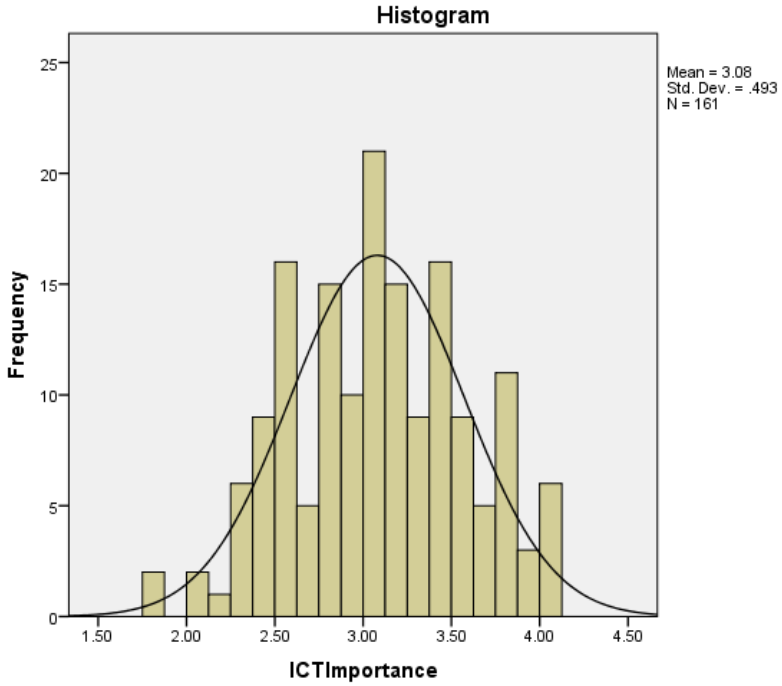


Figure 4. 13. Distribution of variables for importance of ICT in science teaching

4.4.6 TPACK scale

The Cronbach's alpha for TPACK items was very high with a value of 0.96. The mean value was 76.66 which was above the mid-point of 66 and the median value was 79.0. 22 items were used to form this scale and teachers' competence in TPACK. These items were ranged from 1 *(No Competence),* 2 *(Little Competence),* 3 *(Not Sure),* 4 *(Moderate Competence)* and 5 *(Much Competence).* Based on the scoring procedure illustrated by Kabakci Yurdakul et al. (2012) cited in Al Harbi (2014), the mean value (76.66) represented an "Average TPACK" of teachers.

All the 22 items were found to MCAR. For all the 22 variables, the Z score was found to be within the acceptable range of -4.00 to +4.00 showing the absence of any significant outliers. The normality test showed that the data were approximately normal with Skewness and Kurtosis value of less than 1.00 (Table 4.14). The histogram plot (Figure 4.14) further supported that the data were normal.

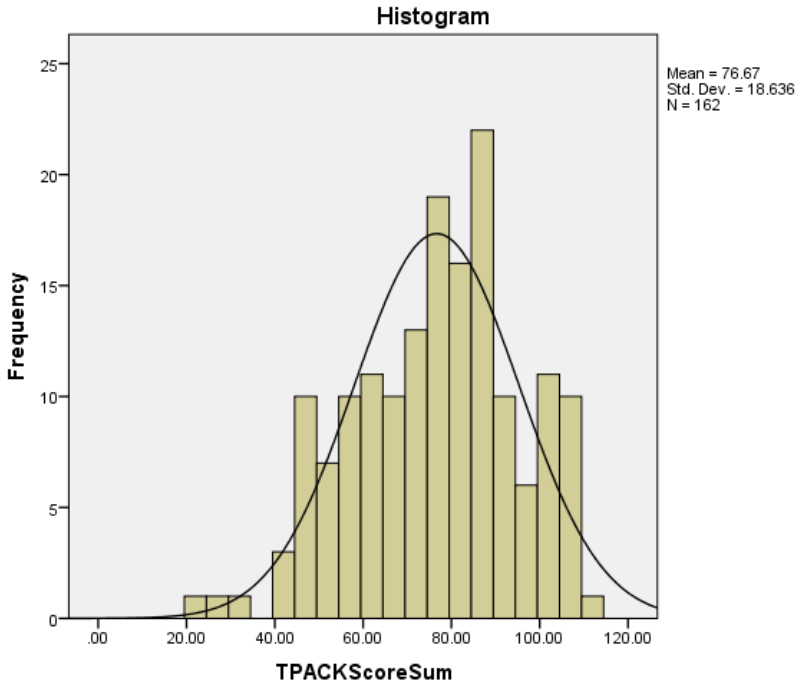


Figure 4. 14. Distribution of TPACK scores

In addition to finding the mean value, TPACK of teachers was further analysed using the score for each item which was based on scoring procedure illustrated by Kabakci Yurdakul et al. (2012) in Al Harbi (2014) to determine their competence. Based on the procedure, for the given sample, the lowest possible score was 22 while the highest was 110. The scores obtained were, therefore, interpreted as follows:

TPACK Score ≤ 60 represented Low level TPACK

TPACK Score between ≥ 60 to ≤ 80 represented Average TPACK

TPACK Score ≥ 80 represented a High Level of TPACK

Based on the above interpretations, 33 teachers (20%) were found to be possessing low level of TPACK, 53 teachers (33%) having an average level of TPACK and 76 teachers (47%) with a high level of TPACK (Figure 4.15). TPACK score is important, since teachers with higher level of TPACK are considered to demonstrate effective pedagogies related to technology integration in teaching (Kohler, 2000).

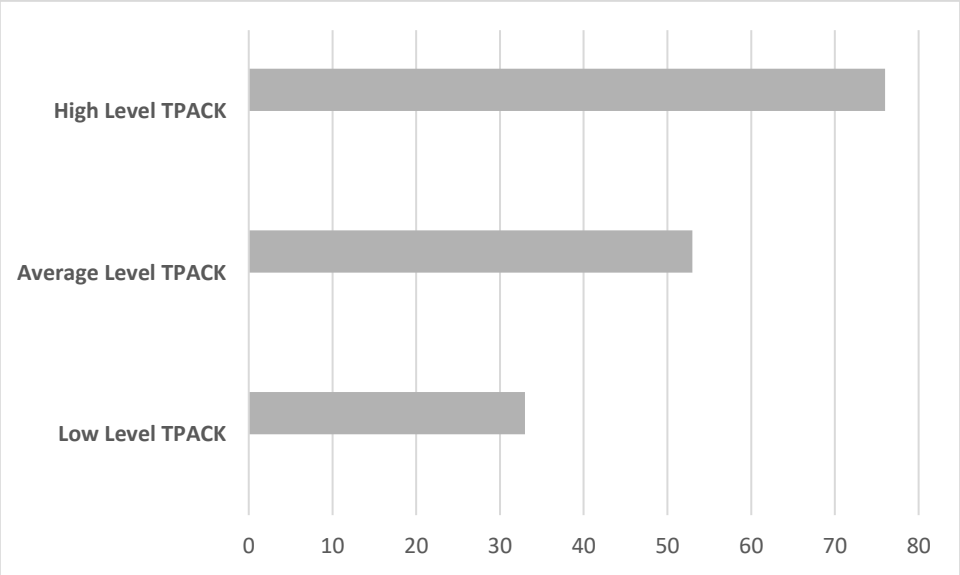


Figure 4. 15. TPACK of Bhutanese science teachers

4.5 Correlations

Pearson's Correlation can have a value in the range of -1.00 or +1.00. The sign of correlation shows the direction of the relationship, while the magnitude or strength is determined by how close it is to the value. So accordingly, a value of -1.00 indicates a perfect negative relationship, +1.00 indicates a perfect positive relationship while a value of zero (0) indicates no relationship. The strength of the relationship can be interpreted as follows: when the correlation is close to +1.00, it means a strong relationship between the two variables; when the correlation is close to zero (0), it means there is a weak relationship between the two variables. For the variables to be statistically significant, the Sig. (2-tailed) value must be less than or equal to 0.05. A Sig (2-tailed) value of more than this value is considered to have no significant correlations. Before the Pearson test, a scatterplot for the variables was obtained to understand

whether they indicate linear relationships. From the scatterplots, it appeared that the variables had linear relationships (Figure 4.16-Figure 4.20).

The data met the requirements for the Pearson test since all data under considerations were continuous variable, approximately normal in distribution, data was random and there were no significant outliers. Pearson's Correlation was conducted to measure the strength and direction of linear relationships between the variables, to determine whether a statistically significant linear relationship exists between the variables. Pearson's test was conducted between TPACK score and ICT variables as shown in the Table 4.17. The results presented showed low to significant positive relationships for TPACK with all the variables. The highest correlation of (r 0.559, p=0.0010) was obtained for TPACK vs. ICT confidence. The relationships of TPACK with ICT daily use (r 0.464, p=0.001) and with ICT science (r 0.456, p=0.001) were similar. The lowest value of (r=0.251, p=0.001) was obtained for TPACK vs ICT importance.

Table 4. 17

Pearson's Correlation

Variables	**Pearson's Correlation**	**Sig. (2-tailed)**
TPACK vs ICT daily use	0.464	0.001
TPACK vs ICT interest	0.321	0.001
TPACK vs ICT confidence	0.559	0.001
TPACK vs ICT science	0.456	0.001
TPACK vs ICT importance	0.251	0.001

4.5.1 TPACK and use of ICT in daily life

The scatter plot shown in Fig 4.16 showed a moderate relationship between TPACK and ICT use in daily life as indicated by the correlation coefficient in Table 4.17 above. The results indicate the possibility of higher TPACK scores associated with greater tendency to use ICT in their daily life.

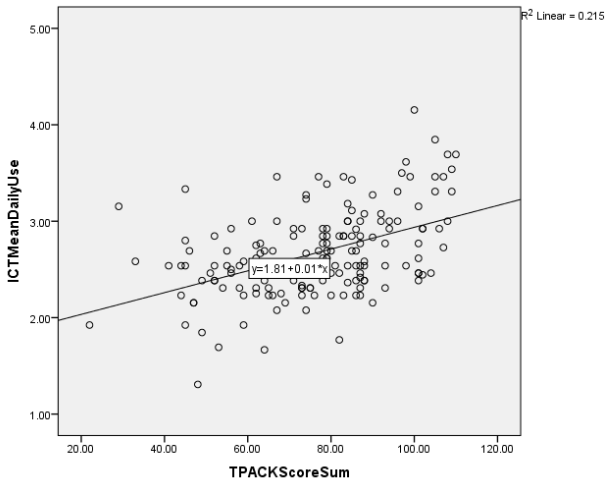


Figure 4. 16. Scatterplot for ICT use daily vs TPACK score

4.5.2 TPACK and interest to use ICT

There is a significant correlation between these two variables. The Sig. (2-tailed) value was less than 0.05. The relationship as indicated from the scatterplot and the Pearson correlation value from the table above shows that there is a positive correlation. In this case too, higher TPACK could be associated with greater interest among science teachers to use ICT.

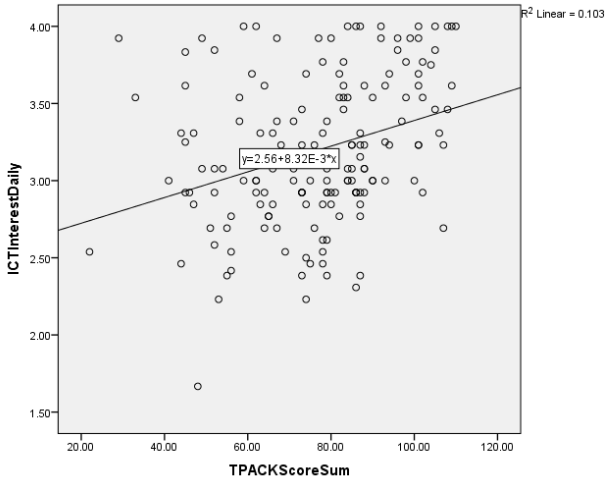


Figure 4. 17. Scatterplot for interest to use ICT vs TPACK score

4.5.3 TPACK and the level of confidence to use ICT

These two variables exhibited a very strong relationship with a Pearson correlation value of 0.559. The Sig. (2-tailed) value was less than 0.05 suggesting that is statistically significant.

This high level of significance indicates close association of TPACK with the confidence of a teacher to use ICT.

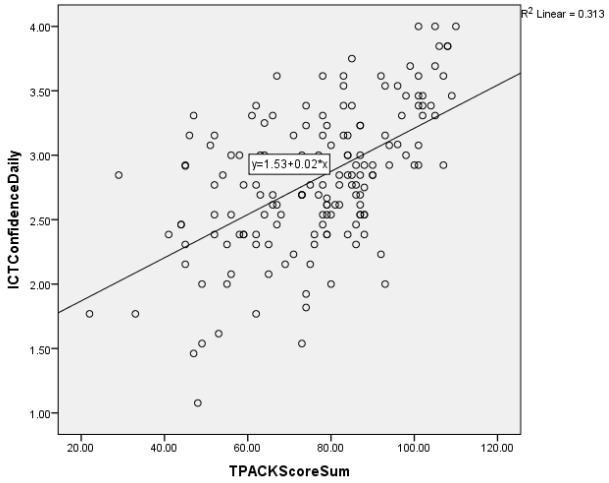


Figure 4. 18. Scatterplot for ICT confidence vs TPACK score

4.5.4 TPACK and use of ICT in science teaching

There was a moderate relationship between these two variables. The Sig. (2-tailed) (2-tailed) value was less than 0.05. The Pearson correlation was 0.456 showing that there exists a strong positive relationship. This is particularly important since this result shed critical information on how ICT is used in the classroom corresponding to their TPACK. It is more likely for high degree of TPACK is related with greater integration of ICT into science teaching.

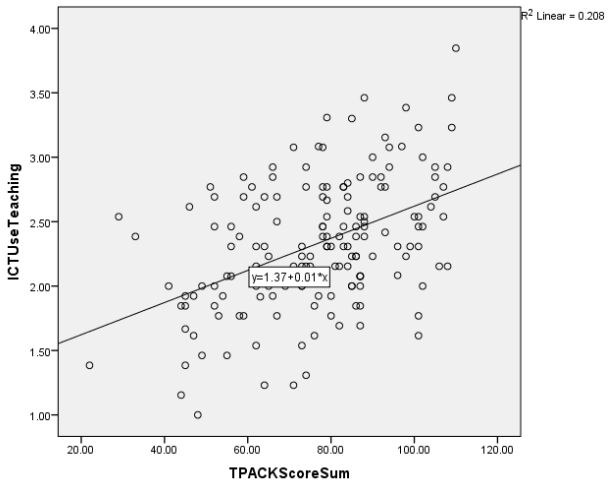


Figure 4. 19. Scatterplot for ICT use in teaching vs TPACK score

4.5.5 TPACK and importance of ICT in science teaching

Compared to other variables, the relationship between these two variables was slightly low. However, the Sig. (2-tailed) value was less than 0.05 proving that it was statistically significant. The correlation value indicates that the relationship is positive between TPACK score of teachers and their recognition of ICT as an important tool for science teaching.

The reason for a comparatively low correlation value between these variables could be due to lack of understanding among teachers the role of TPACK or ICT can play in science education.

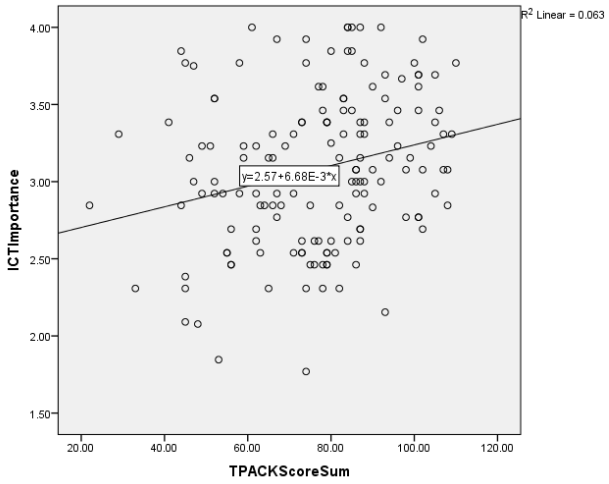


Figure 4. 20. Scatterplot for ICT importance vs TPACK score

4.6 Levene's Test

Levene's test was applied to test the significance of differences between population means as described in the Methodology chapter, section 3.10. The results are presented in Table 4.18. As shown in (Table 4.18) *p*-value was greater than the significant level of 0.05 except in the case of TPACK score. Therefore, it can be stated that the differences in mean score for male and female teachers were non-significant; meaning both male and female science teachers scored the almost the same mean for the given variables. In case of TPACK, it is assumed that there is a significant difference in mean between the two groups.

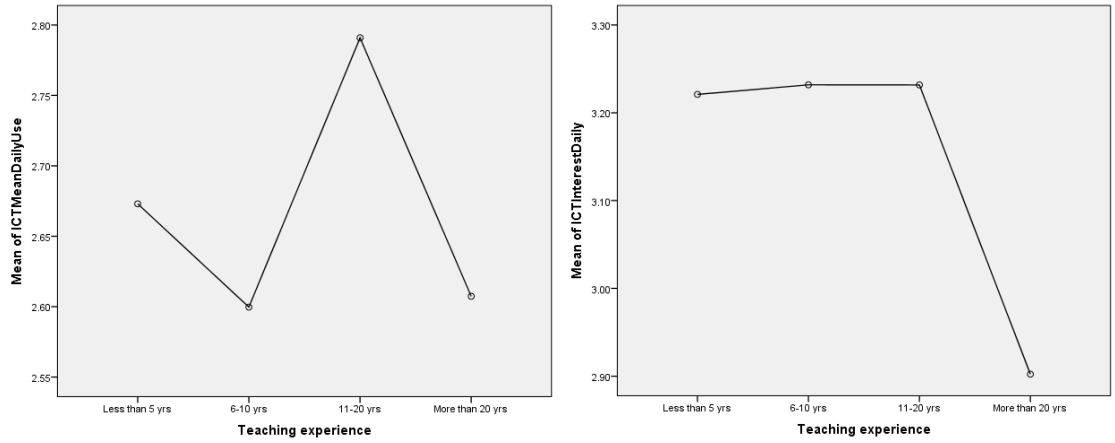
Table 4. 18

Levene's test

Scale	Levene's test for equality of variances	
Mean/Variables	**p-value**	**t-Test**
ICT daily use	0.079	-0.54
ICT interest	0.313	-1.38
ICT confidence	0.417	-0.09
ICT use in science	0.103	-1.94
ICT importance	0.111	-0.62
TPACK score	0.024	-0.98

4.7 Analysis of Variances (ANOVA)

ANOVA was done as described in Methodology chapter, section 3.10. For the current sample, the differences in means were found not statistically significant since the p-value obtained were greater than the significance level of 0.05. The main reason for this was due to inadequate number of samples in each group under consideration. However, by interpreting from the mean plots (Figures 4.16), it was found that the mean value for teachers with 11-20 Years of teaching experiences were prominent. The trends indicated that these group of teachers tended to use ICT more frequently in their daily life including use in their teaching. They showed high interest towards the use of ICT coupled with high confidence level. Majority of them possessed an average level of TPACK.



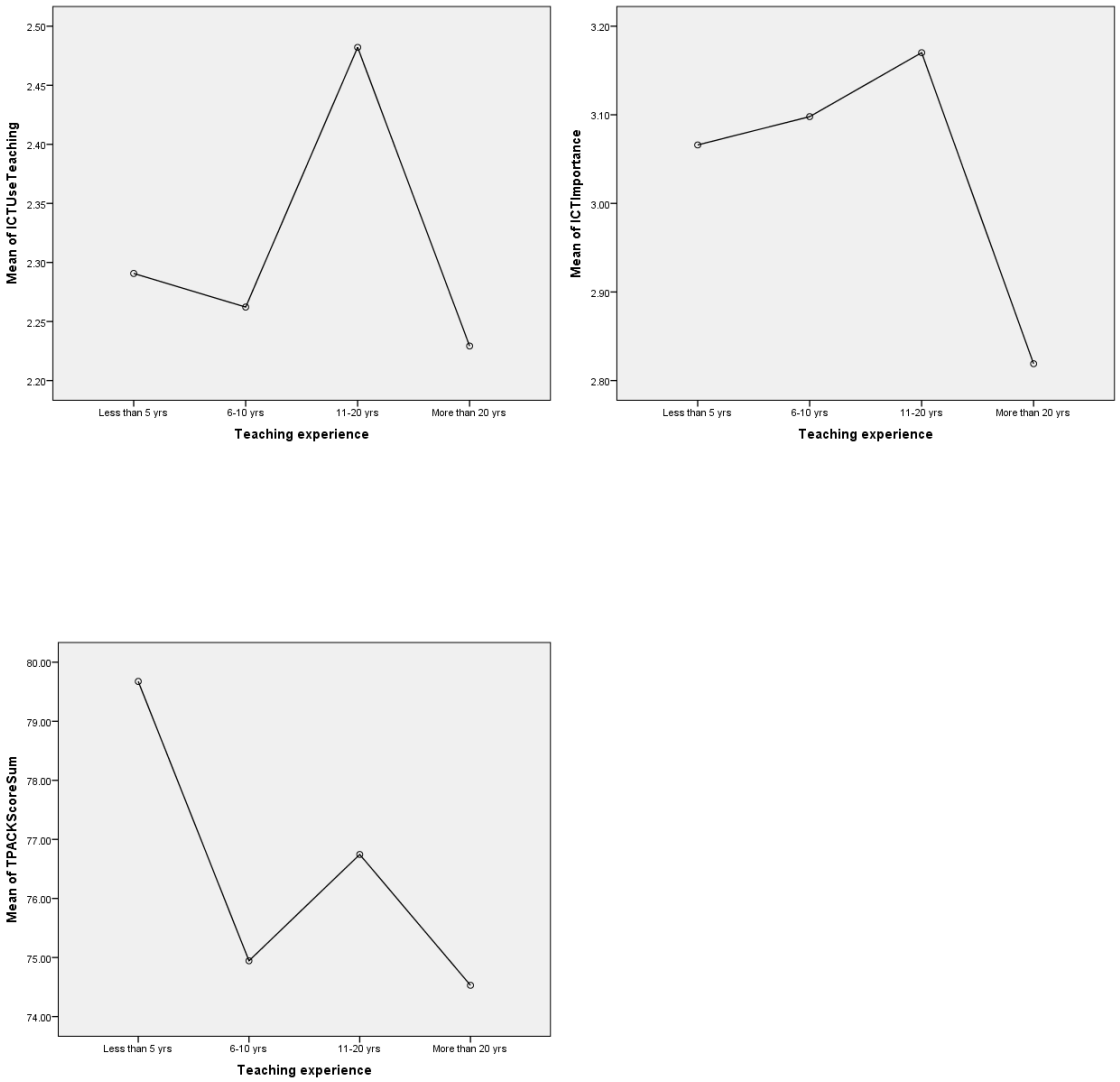
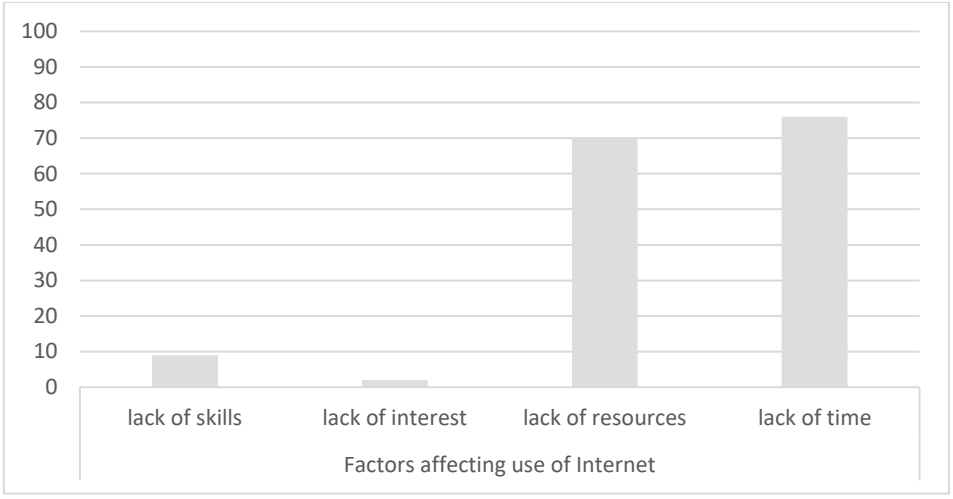


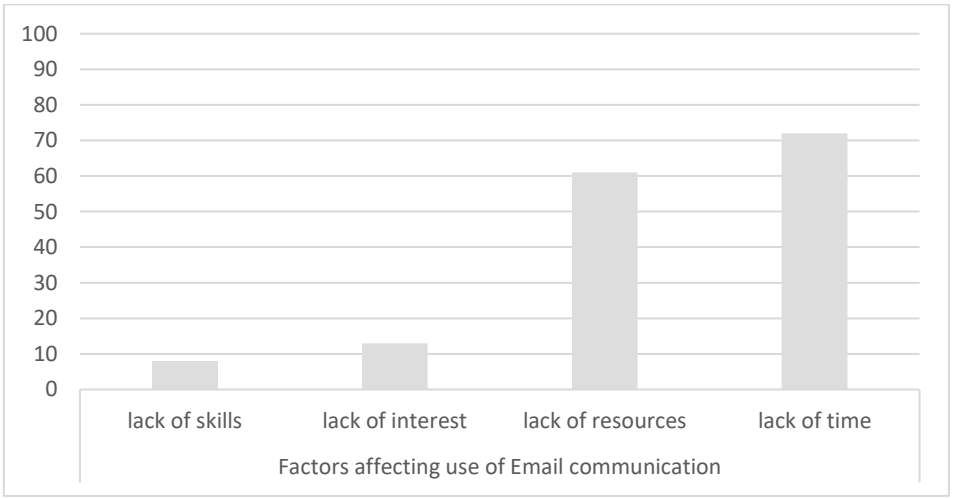
Figure 4. 21. Mean plots (teaching experience vs TPACK)

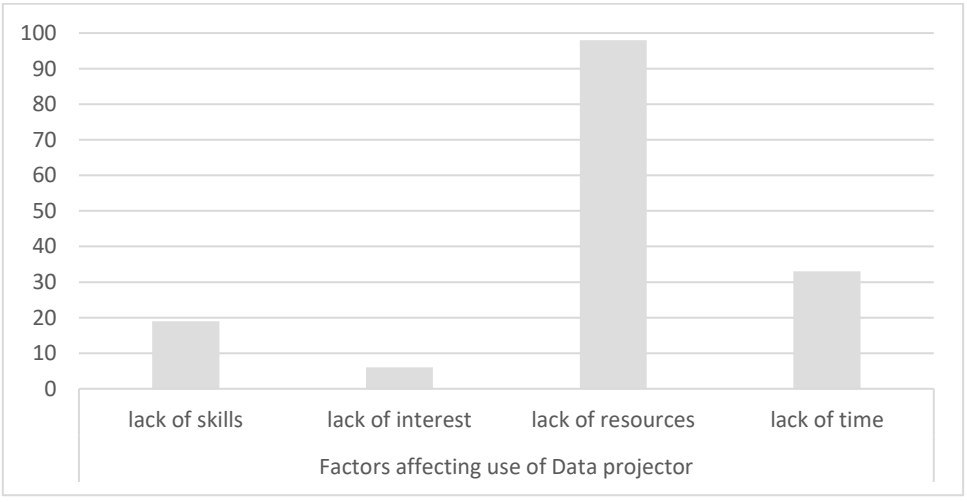
4.8 Cross Tabulation

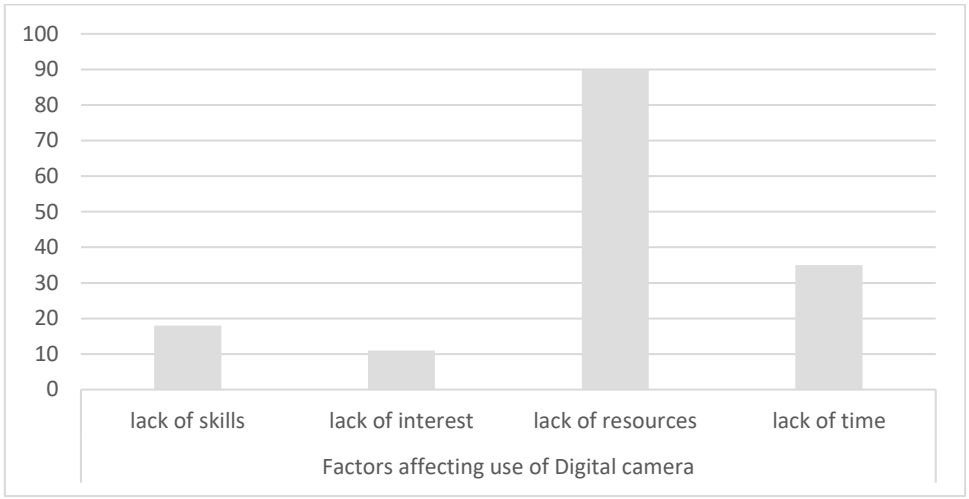
Cross Tabulation is a quantitative research method used for analysing the correlations between two or more vairables. It is used to compare the results for group of vairables to another. Cross tabulation provides patterns and trends associated with the data. For the current study, cross tabulation was performed to analyse the factors affecting the use of various ICT variables (13 items) by the science teachers. The final results are explained with the help of bar graphs. From the graphs (Figure 4.22), it showed that two factors namely lack of resources and lack of time dominated the rest of cause affecting the use of ICT by sceince teachers. In general, it has been shown that Bhutanese science teachers possessed adquate skills and high interest to use

ICT except for the use of Databases, E-journals and Web designing. These findings correlated to the results obtained and explained in the previous sections.





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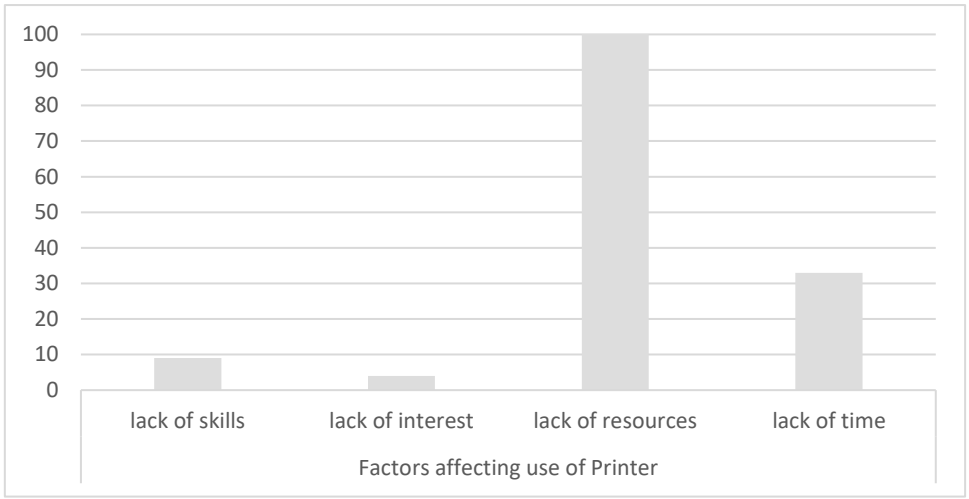
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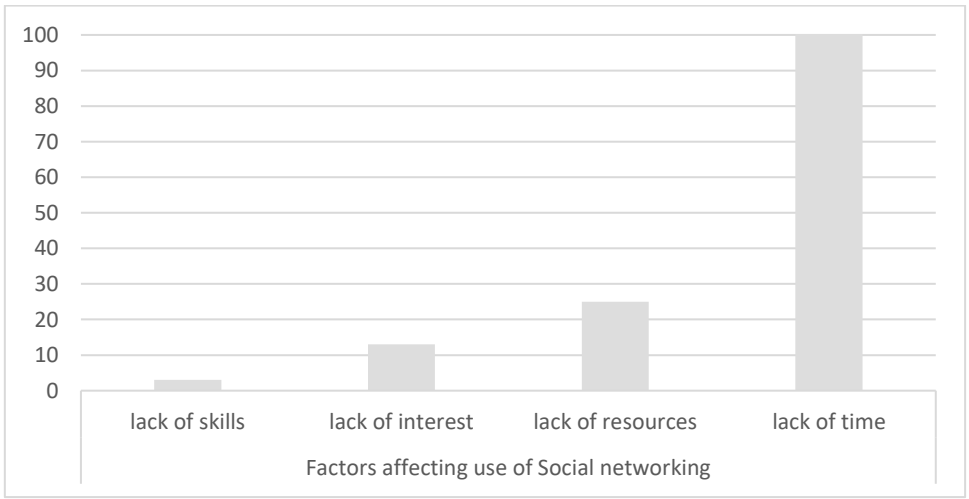
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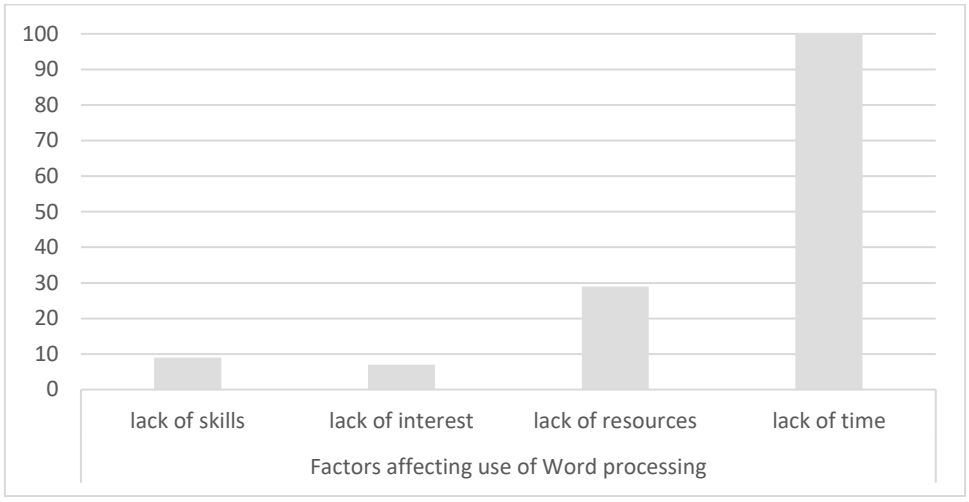
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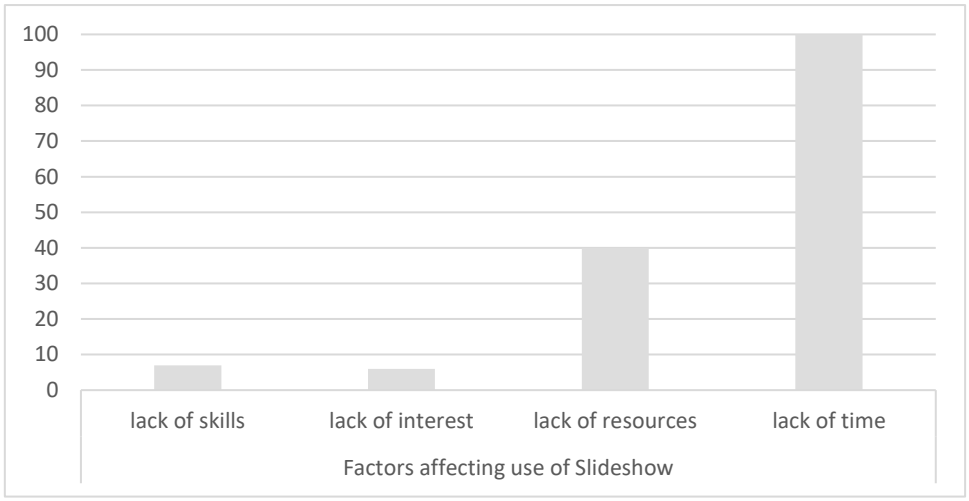
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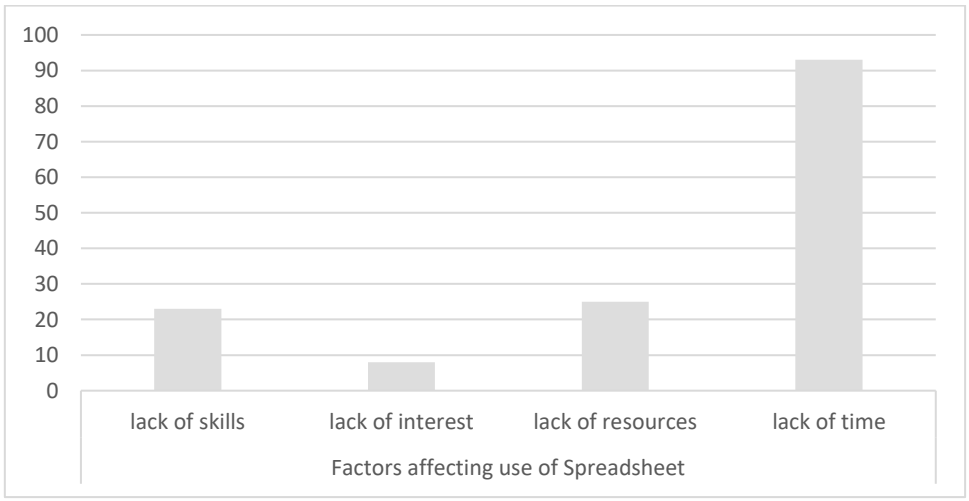
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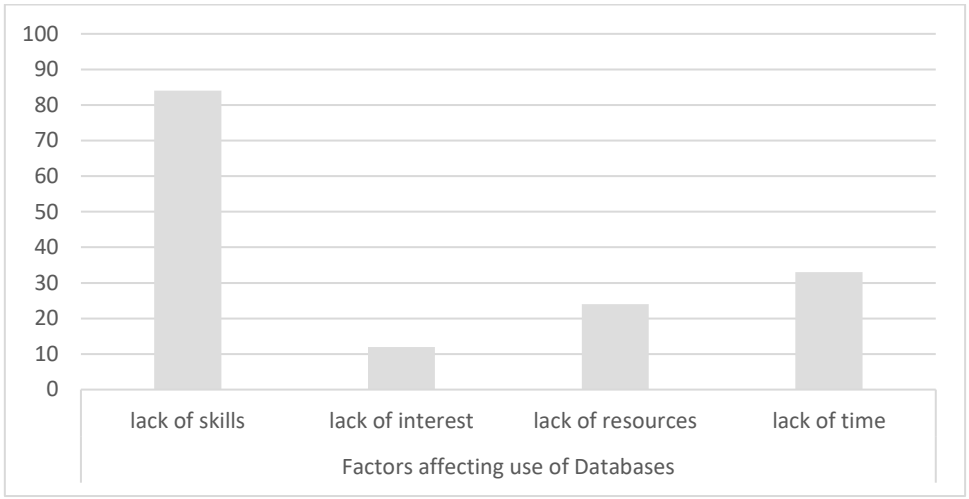
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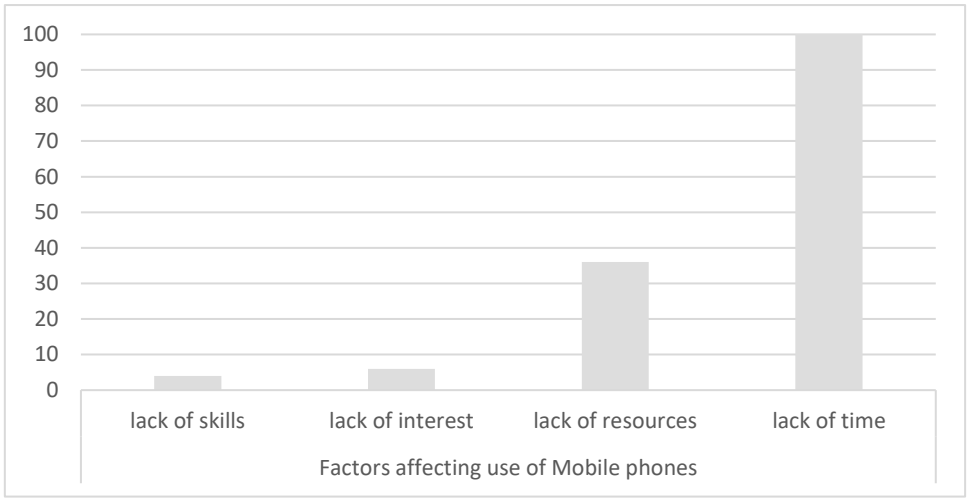
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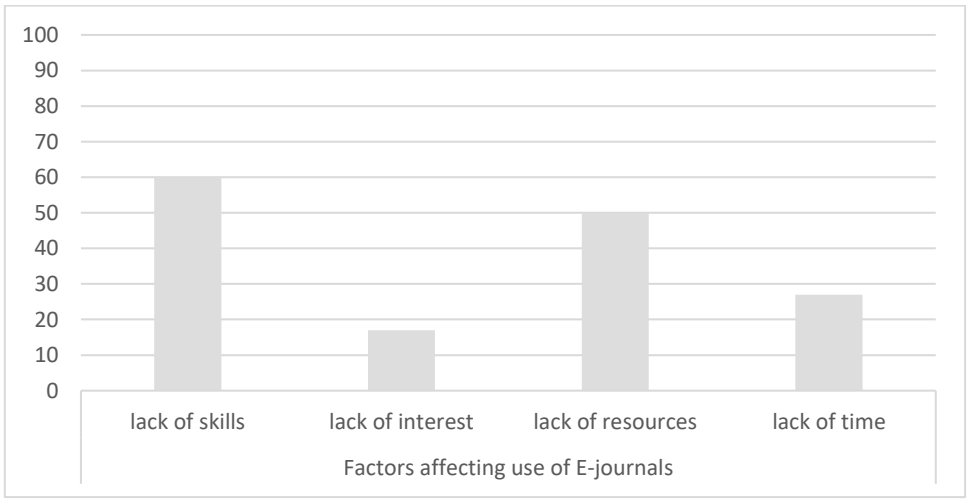
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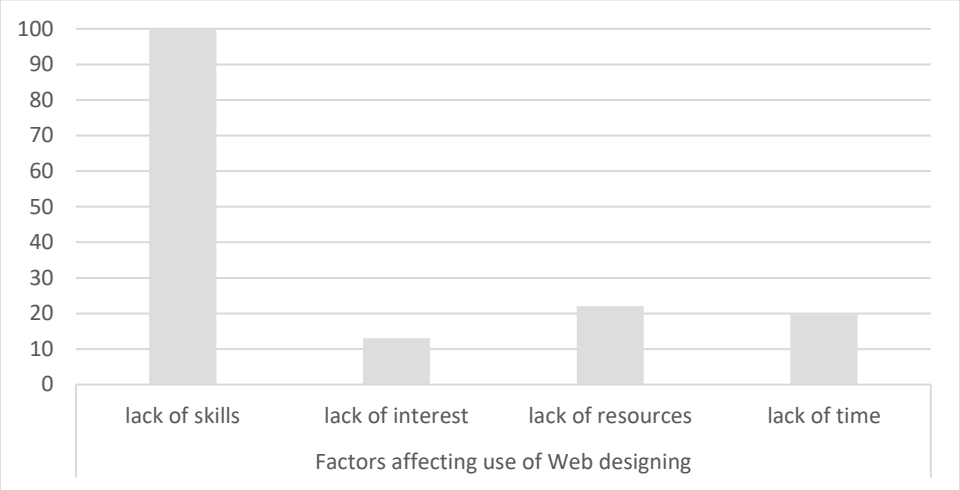

Figure 4. 22. Factors affecting use of ICT

4.9 Summary

Data collected from the questionnaires filled by 162 middle secondary science teachers was subjected to quantitative analysis using *IBM SPSS Statistic Version 24* to obtain various demographic information related to the respondents. The data was then used to gather descriptive statistics to form the item scales. Six scales were formed from these analyses. These are: (i) Use of ICT in daily life; (ii) Interest to use ICT; (iii) Level of confidence to use ICT; (iv) Use of ICT in science teaching; (v) Importance of ICT in science teaching, and (vi). TPACK scale. In addition, 13 items were used for the scale related to ICT whilst 22 items were used for TPACK scale. The mean and standard deviation for each scale was obtained and explained. These scales were then subjected to further analysis which included checking for any missing values, checking for outliers, normality and conducting reliability test. The missing values were checked by applying Little's MCAR test, outliers were checked by performing z-score test, normality was verified using Skewness and Kurtosis values and by plotting normality probability plot while the reliability test was assessed determining Cronbach's alpha. The analysis of scales led to description of each scales.

In addition, Pearson's test of correlation and t-test was conducted to identify relationships between the variables and to find out any significant differences among the respondents. Furthermore, Analysis of Variance (ANOVA) was performed to compare the means however, no significant differences were obtained due to lack of enough samples under

consideration. Finally, quantitative data was analysed to determine the factors affecting the use of ICT by science teachers applying cross tabulation.

CHAPTER 5: QUALITATIVE ANALYSIS (Case Studies)

This chapter reports on the findings related to the case studies on eight selected schools. As stated in the Methodology chapter, this case study consisted: a historical background and achievements of the school, semi-structured interviews on the perceptions and attitudes of teachers regarding use of ICT for science teaching in their schools and a focus group of students taught by these teachers. While the qualitative analysis supported and helped to address all the research questions raised above, the school-teacher-student continuum provided specific answers mainly for the third research question: 3. What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms? It also provided answer to the fourth research question: 4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms? Both these questions were related to school dimensions of ICT use.

A total of eight teachers and three groups of students participated in interviews and focus group discussion. The qualitative data helped to gather additional information about responses to questionnaires and better addressed the research problem than either type by itself (Creswell, 2006).

For the interviews, 20 teachers were marked as the potential participants based on their mean score of ICTs use in science teaching and the TPACK score which was obtained from the quantitative data. From these 20 teachers, eight of them agreed to participate in the interviews (Table 5.1). Out of this, seven teachers agreed to be interviewed over video conference while one teacher agreed to be interviewed in person. In addition, the researcher was able to conduct interviews with three groups of students belonging to these eight teachers from three different schools. While the intention was to conduct group discussion with students of all the eight teachers, only three teachers/schools consented to conduct interview with their students while for the rest, some teachers denied their consent and others were in far off places in Bhutan that impeded time and resources. Students of the selected group of teachers who participated in filling the questionnaires and who agreed to be interviewed were invited to attend a focus group discussion in person. Permissions were obtained through the teacher concerned and the school authority for the conduct of interviews for students under the age of 18. While inviting the teachers for the interview, researcher also considered their age, gender,

qualifications, teaching experience and the location of schools to get a clear understanding of ICT situation in Bhutan.

5.1 Interview Background

A semi-structured interview questions were used as the main tool for conducting the interview. The questions were framed in such a manner to gather additional information on quantitative data. The questions included various aspects of ICT use in daily life, their interest, level of confidence, use in science teaching and questions that tested their TPACK.

In the case of teacher interviews, the information obtained from the interview was divided into four main themes/patterns (Confidence/Skills, Use in science teaching, Importance and Resources). Based on the content of the interview responses, they were allotted to one or more of the four themes.

While for the student's focus groups, the information was divided into three main themes/patterns (ICT use in classroom, ICT use outside the classroom and Resources). Researcher considered these themes within the information to gain additional insights on ICT skills, ICT knowledge, ICT use and factors affecting ICT use. Here too, the responses were allotted to the related theme/s. Some of the responses were classified as belonging to two different themes due to its relevance to both the themes. After this, the number of occurrences of the themes were determined and was used to derive to a conclusion.

In the following presentation of results, pseudonyms in the form of codes were used for schools, each teacher and the student groups to protect their identities. Pseudonyms have been used when specific response to questions in the focus group need to be attributed to specific student.

The demographic characteristics and mean score of use of ICT in science teaching of the eight teachers interviewed, are given in Table 5.1. The colours for teacher interviews and student focus groups are given merely to distinguish the themes easily. Each answer is allotted to a theme based on the content of the answer and the theme colour is given.

Table 5.1

Teacher participants' details (Interview)

RANK	ID	ICT Mean	Age	Gender	Experience	Qualification
1	Sc16R04	3.85	30-39 yrs.	Male	11-20 yrs.	B.Ed.
4	Sc01R01	3.38	30-39 yrs.	Female	6-10 yrs.	Master
5	Sc24R01	3.31	30-39 yrs.	Male	11-20 yrs.	B.Ed.
8	Sc39R03	3.23	25-29 yrs.	Male	6-10 yrs.	PGCE/PGDE
10	Sc05R01	3.08	40-49 yrs.	Male	11-20 yrs.	Master
13	Sc25R02	3.08	30-39 yrs.	Female	6-10 yrs.	B.Ed.
14	Sc19R03	3.00	30-39 yrs.	Male	Less than 5 yrs.	PGCE/PGDE
20	Sc40R02	2.92	Above 50 yrs.	Female	Above 20 yrs.	B.Ed.

5.2 Case 1: School Sc40

This section describes the school settings and the interview results of a teacher from school ID Sc40. The school Sc40 was a middle secondary school established in the early 1960s as one of the only schools in the capital city of Bhutan. It was upgraded to a middle secondary school in due course of time owing to the demand and need of the changing times. Currently the school has more than 800 hundred students studying from pre-primary to Year 10 with more than 60 teaching staff. Historically the school has maintained a very high standard in terms of academic performance and other co-curricular activities. The school has one fully equipped computer laboratory with Internet connections and printing facilities. During school visit for student interview, it was learned that another similar computer lab was ready for student and teachers use.

5.2.1 Teacher Sc40R02 background

The participant Sc40R02, a science teacher was selected for the interview based on the responses to the questionnaires, which was filled as a part of quantitative method for the study. She was the school IT head and taught two subjects (i.e., IT science and Chemistry) in Year 9 and Year 10. The participant details are summarised in Table 5.2. The means score for ICT use in daily life was 3.85 representing the use "Frequently or Once a week". She scored the maximum mean in terms of "level of confidence to use ICT" with a mean of 4.00 representing "Very confident". Her mean score for "use of ICT in science teaching" was 2.92 representing "Once in a month". She considered ICT "Important" with a mean of 3.38. She scored 105 out

of 110 in the TPACK score. This TPACK score represented a “High level of TPACK” on TPACK scale.

Table 5.2

Quantitative results (Teacher Sc40R02)

ID	Demographic		ICT scores (mean/sum)					
Sc40R02	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	50+	Female	3.85	3.85	4.00	2.92	3.38	105.00

5.2.2 Interview analysis (Teacher Sc40R02)

The interview with this participant was conducted via video conference using Facebook Messenger application. The information gathered was processed as described in section 5.1. Table 5.3 provides teacher Sc40R02 interview records.

Table 5.3

Interview records (Teacher Sc40R02)

Interview records and analysis for teacher Sc40R02					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	I use ICT to teach abstract concepts in chemistry.				
	To motivate children and enhance the level of understanding.				
	I am in upper hand on using ICT as the IT head.				
	Using ICT becomes a visual mode to present topics.				
	It helps to understand the concept and processes better.				
	Pedagogies becomes more diverse and generate more interest in children.				
	To encourage children to have love for the subject.				

Question 2	**What are you focusing on now in the use of ICT?**				
Responses	At present Chemical bonding and periodic table.				
	Less access for students to use computers due to a smaller number of computers.				
	Use ICT to teach the topic about five or six times.				
	Used ICT in form of games, songs and YouTube videos.				
	Main aim to motivate student to love the subject.				
Question 3	**What is the value in having your students use a computer?**				
Responses	Daily values attached with ICT.				
	More responsible, more creative and analytical.				
	Overall become a better person with ICT skills.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	ICT fits quite appropriately with subjects like chemistry.				
	Being a senior teacher, I find lots of difference in teaching. using ICT as compared to traditional methods.				
	Using ICT especially in chemistry fits very well as per my experience.				
	With development and use of technologies I see lots of differences in teaching learning process.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	I am the head of IT in my school and contributed number of things.				
	I set up local network for all the computers with a server. sharing local files.				
	ICTise the school				

	I created an individual account for each teacher. They can log in from any computers in the campus.				
	I designed the school website and manages it.				
	I created result processing software and do school result analysis.				
	Also designed a simple item analysis software.				
	Oriented other teachers on this software.				
	Created software to track students' progress.				
	I am also aware of Google apps and oriented other teachers, but only a few uses it.				
	Created email ID for teachers in school domain.				
	Designed school magazines, school dairy and newsletter.				
	I wish to make library management for school.				
	I want to create games, quizzes using hot potatoes. software relevant to topics and chemistry subjects.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	Result making software shared with one central school.				
	Item analysis software shared through one of a teacher's colleagues to another school.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	I cannot use ICT very often in chemistry because there are so many constraints				
	I use once a month or twice a month at the most.				

	Too many constraints due to lack of equipment, time and space.				
	A new lab is opening in the school is hoping to use more.				
	Chemistry students use ICT twice a month on an average.				
	Students work in groups but soon there will more computers and students can use individually.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved?** **How do you decide on the strategy you use?**				
Responses	I use ICT to teach abstract concepts by using visual representations, games and videos.				
	On an average use twice, a month due to equipment shortages.				
Question 9	**What activities have you used computers for in the last term?**				
Responses	Used Google app to create classroom, assigned tasks for IT students but not in chemistry.				
	Trying to use the Google app with one of the chemistry assignments.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	I wish my students to become IT literate.				
	Use Google app for my IT class.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	Not assessed with chemistry students but for IT students done in Google app.				

Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	Nowadays without IT knowledge they will reach not far (IT is very important).				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	In this digital world students need ICT knowledge.				
	If they have love for ICT they become information seeker and navigator.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	Inspire and motivate my students.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	As of now it is me who decides to use ICT with students.				
	With regards to IT knowledge I must guide them since student's lack knowledge.				
	I allow my students to browse internet to seek information.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	As IT teacher I am quite good at using Google apps.				
	I can program small programming.				
	I do e-learning myself (self- learning).				
	I want to be a useful person to the school and make work easier.				

Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I see myself as a IT literate and some who can motivate my students to use ICT.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	ICT motivates the users.				
	Teaching strategy becomes more attractive.				
	Knowing IT means becoming more confident.				
	IT is visual and enhance learning.				
	Cover the syllabus in a faster time/save time.				
	Simply using a PowerPoint is not ICT for me.				
	I don't see any negative in using ICT.				
	However, since students have different learning styles and comes from various background a ICT lesson may not be favourable for some of them.				
	When it comes to teachers, we must competent to use ICT.				

5.2.3 Discussion on interview (Teacher Sc40R02)

This section reports on the findings based on the themes for the teacher Sc40R02. As mentioned in section 5.1, four themes were identified: teacher's level of confidence, use of ICT in teaching, importance attached to ICT and factors associated with resources.

5.2.3.1 Confidence/Skills

Teacher Sc40R02 was found to be very confident with use of ICT. The teacher used her skills in the classroom and the school environments. She was observed to be confident in higher level of ICT skills such as web designing and use of online applications. On several occasions, the teacher participants strongly proved that her confidence/skills in ICT was superior. The reason

for this could be because she was the head of IT department in her school. For instance, she mentioned, *"I am in upper hand on using ICT as the IT head".* She was found to be actively engaged in contributing ICT related resources to her school and other teacher colleagues. For instance, she said,

> I set up local network for all the computers with a server sharing local files, I created an individual account for each teacher, teachers can log in from any computers in the campus can access the files from the server, I designed the school website and manages it, I created result processing software and do school result analysis I am also aware of Google apps and oriented other teachers, I designed school magazines, school dairy and newsletter.

5.2.3.2 Use in science teaching

The teacher used ICT skills in her classroom most of the time. From the information, it can be stated that she constantly tried to use ICT with her teaching although she complained of resources constraints. Her focus with ICT with regards to science teaching was for teaching abstract concepts, to motivate and generate interests in students and to vary her teaching strategies. She mentioned, *"I use ICT to teach abstract concepts in Chemistry and to motivate my students thereby enhancing their level of understanding. Using ICT is a visual form of teaching and pedagogies becomes more diverse and generate more interests in children (students)"*. The teacher responded fully agreed that ICT was suitable to use and perfectly fit in her science teaching overall. *"ICT fits quite appropriately with subjects like Chemistry and I find lots of difference in teaching while using ICT as compared to traditional method of teaching"*. However, she was concerned whether ICT could cater to all groups of students, *"However, since students have different learning styles and comes from various background ICT lesson may not be favourable for some of them".*

5.2.3.3 Importance to ICT

The teacher Sc40R02 considered ICT to be very important both for students and teachers. She repeatedly stated that ICT is important in this global world. Some of the main reasons she stated were because ICT: motivated and enhanced the level of understanding; encouraged students to have love for the subjects and students becoming more creative; therefore, making students more confident in this modern age of technology, as well as a reduction in workload of teachers. She clearly mentioned, *"ICT motivates students and enhance their level of understanding,*

students become more responsible, more creative and analytical and using ICT helps me to cover the syllabus faster".

5.2.3.4 Resources

Teacher Sc40R02 has shown concerned relating to resources in her school. She stated that although she is interested to use ICT with her students and colleagues it is not possible due to lack of available resources. She was limited to use ICT due to shortages or lack of ICT resources. Similarly, her students were also disadvantaged as there are not enough computers in the school. She stated:

> students have limited access to computers due to a smaller number of computers. I am not able to use ICT as frequently as I would love to due to resources constraints and space therefore, on an average we utilise ICT only twice in a month.

5.2.4 Students focus group analysis (Group Sc40R02#G01)

This section reports on the interview conducted with a group of students belonging to a teacher Sc40R02. A total of five students (three boys and two girls) from Year 9 attended the interview. The teacher Sc40R02 taught Chemistry for them. The location of the interview was at the school premises of school Sc40 in the capital city. The discussion was carried out inside one of a small meetings hall in the school. To provide confidence and confidentiality to the students, the teacher in consideration was not allowed during the conduct of interview, only the researcher and students were present throughout the interview. The information obtained from the student interview is summarised in Table 5.4. Like the teacher interview, the information was analysed by identifying the key points that were relevant to the scope of study. These key points were then used to link with the teacher's information to arrive to a conclusion.

Table 5.4

Interview records (Students-Sc40R02#G01)

Interview records and analysis for students Sc40R02#G01				
Question 1	**How often do you use ICT in your class?**	**Themes/Analysis**		
		ICT use in Classroom	**ICT use outside the classroom**	**School Resources**

Responses	Once in a week in classroom.			
	In IT class we use three times in a week.			
	Almost every day in personal life.			
Question 2	**Give some examples of activities carried out using ICT/computers?**			
Responses	Presentation using the projector.			
	Project work done by student themselves.			
	Use ICT during practical examination.			
	Used computers to research information on project works.			
	Teachers teach us using ICT in the form of presentation we learn better.			
	Showing video by teacher is also more effective.			
	Makes learning more interesting when teachers use.			
	Using ICT in Biology is more effective compared to Chemistry and Physics.			
	Teacher showed to make a presentation.			
Question 3	**Do you have opportunities to interact with ICT in your science classroom?**			
Responses	Not much.			
	Once in a month.			
	Three times in a week during IT class.			
	Yes, we can stay back after school and use.			
	Go along with teacher during school hours.			
	can use computers without teachers after school.			

Question 4	**Give some examples of ICT that you are confident in your learning?**			
	Using mobile phones. Making videos.			
	Taking pictures. Typing skills.			
	Browsing internet, Google search.			
	Use Facebook and WeChat.			
	Some skills are learned at home and some in school.			
	More ICT skills learned at home.			
Question 5	**According to you what is the ICT status of your school?**			
Responses	Before there was shortage but now we have new computer laboratory.			
	Our teachers are more competent than us.			

5.2.4.1 Discussion on students focus group (Sc40R02#G01)

The findings from student group Sc40R02#G01 belonging to teacher Sc40R02 showed that there was a frequent use of ICT in their learning environment and it indicated that they used ICT in their learning processes such as gathering information from the Internet and completing their project works. Students mentioned that their teacher's use of ICT made the lessons more enjoyable and interesting. Student Dorji stated that *"when our teacher uses ICT (videos/presentations) we learn better"*. Similarly, student Tashi stated *"learning becomes interesting when teacher use ICT'*. From their responses, it was very clear that student's participants were fully confident in using basic ICT skills such as accessing Google apps, YouTube videos, browsing the Internet, social networking, typing skills and making presentation using projectors. These skills were found to have learned mainly outside the classroom since students mentioned that there were limitations for ICT use in the classroom due to resource constraints. Student Serchung stated, *"we use ICT once in a week"* while another said, *"I use ICT almost every day outside the classroom"*. A student Tumchi clearly stated that *"we do not have opportunity to use ICT in classroom, we use it once in a month"*. This is in line with what the teacher had responded in terms of ICT use frequency. (i.e., once in a month on average).

5.2.5 Conclusion

The participant teacher Sc40R02, a science teacher from school Sc40 was observed to be an active user of ICT. The interview analysis supported the quantitative result. Information analysed from students' interview showed that she used ICT once in a month in her teaching. For instance, she provided students the opportunity to obtain information from the Internet for their projects. She also stated that she utilised videos, pictures and games to aid her teaching although this was not fully supported by her students' responses. From the analysis, it was also learned that she played an important role in use of ICT for teaching and learning communities in the school as she shared her skills and knowledge extensively. However, it was found from her interview analysis that she faced ICT resources constraints to implement ICT in her teaching and learning processes.

5.3 Case 2: School Sc16

School Sc16 was a senior secondary school in a western part of the country. The school was established in the early 1990s and was recently upgraded to a central school catering to students from nearby lower secondary schools to complete a senior secondary education. Presently the school has more than 1000 students studying in Year 9 to Year 12 with about 45 teaching staff. The school has a record of producing an outstanding result in academic performance in board examinations especially in Year 12 results. The school has two fully equipped computer laboratories with Internet connections and a separate printing, photocopying and scanning facilities for teachers and students.

5.3.1 Teacher Sc16R04 background

The participant Sc16R04 taught Physics in Year 9 and Year 10. He scored some of the highest mean scores amongst all the respondents who participated in the survey. The mean for use of ICT in daily life was 3.69 representing "Frequently or Once a Week". The mean for interest to use ICT was 4.00, meaning "Very Interested". His mean for level of confidence to use ICT was 4.00 indicating "Very Confident". He scored a mean of 3.85 in ICT use in science teaching representing "Once in a Week". The mean for importance of ICT in science was 3.77 representing "Important". He scored 100 percent in TPACK score (110 out of 110). This represented the "Highest Level" of TPACK on TPACK scale. Table 5.5 shows the details of quantitative results for teacher Sc16R04.

Table 5.5

Quantitative results (Teacher Sc16R04)

ID	Demographic		ICT scores (mean/sum)					
Sc16R04	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	30+	Male	3.69	4.00	4.00	3.85	3.77	110.00

5.3.2 Interview analysis (Teacher Sc16R04)

The interview with this teacher participant was conducted via video conference using Facebook Messenger application. The information gathered was processed as described in earlier section 5.1. Table 5.6 provides details of teacher Sc16R04 interview records.

Table 5.6

Interview records (Teacher Sc16R04)

Interview records and analysis for teacher Sc16R04					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	To go paperless in line with government policy.				
	User friendly.				
	Information at one place.				
Question 2	**What are you focusing on at the moment in the use of ICT?**				
Responses	Submitted a proposal to school management to conduct workshop among teachers on Google apps for education.				
	Try to use digital technologies whenever possible in my teaching.				
Question 3	**What is the value in having your students use a computer?**				
Responses	They are kept actively engaged by using ICT.				
	I feel that they learn better using ICT				
Question 4	**How does ICT fit into your teaching overall?**				

Responses	It is quite fitting with Physics.				
	They get actively engaged.				
	Teacher needs to prepare in advance.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	In my previous schools I designed a school website.				
	In previous school conducted PD program among teachers				
	At present school will try to go for paperless idea.				
	School will soon get internet package and will conduct orientation on Google apps.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	I do share my IT knowledge and learn from them.				
	Since I am interested, I encourage other teachers to embrace ICT in modern times.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	If we use ICT students will be better engaged and learn better but resources constraints.				
	Less computers.				
	Students use computers whenever they are free.				
	To seek additional information on top of what they have learn in classrooms.				
	Encourage research projects but lack of time and resources.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	Have not prepared a specific lesson using ICT in Physics but have used ICT as and when it was necessary and convenient.				

Question 9	**What activities have you used computers for in the last term?**				
Responses	I taught Physics concepts using PowerPoint and videos.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	Yes, I did similar activities in my previous school.				
	Whenever students are bored with traditional methods of teaching, I used to take them to computer laboratory.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	Not always as it is time consuming Not enough facilities. Prepare questions and students can submit the responses using ICT.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	Sometimes I fear that if students are not monitored properly, they may land up in wrong ways. If we monitor properly students can contribute to nation building.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	21st century students will learn better Teaching will become easy but tough preparation.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	I am a meditator or a bridge to them If unattended students may learn unethical/non-educational items We need a clear idea what to let students to learn.				

Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
	I consider students view as well and we must understand their need and decision However, we as a teacher should guide.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I have basic skills like presentation, writing digital (electro pen).				
	I attended a short seminar and learn from there how to use electro pen; I feel it has huge potential in Bhutan.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I feel satisfaction when I use and when the concept has been delivered well to my students.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	Students learn better using ICT.				
	But at the same time Students need to be monitored.				
	Allow students to use ICT in a proper manner.				
	Encourage use of e-books.				
	Present students are happy to go after ICT.				

5.3.3 Discussion on interview (Teacher Sc16R04)

This section reports on the findings based on the themes for the teacher Sc16R04. As mentioned in section 5.1, four themes were identified: teacher's level of confidence; use of ICT in teaching; the importance attached to ICT, and factors associated with resources.

5.3.3.1 Confidence/Skills

Teacher Sc16R04 was an active user of ICT in his school. He was involved in designing and managing school websites in his previous school. He had received a training related to ICT through school development scheme. He was planning to conduct a professional development to his teacher colleagues on the use of Google apps. In addition, he was found to be possessing skills such as use of a digital electro pen that helped him enhance his teaching. He stated:

> I have submitted a proposal to school management to conduct workshop among teachers on Google apps for education, in my previous schools I designed and managed school website and I conducted PD program among teachers. [Our school] will soon get internet package and will conduct orientation on Google apps.

5.3.3.2 Use in science teaching

Teacher Sc16R04 used ICT in his teaching once in a week. While he responded that he allowed his students to use computers he mentioned that he was not able to use ICT in his teaching on regular basis due to lack of resources and time. He had used PowerPoint and videos to teach concepts in Physics. He responded that ICT was suitable to use in subjects like Physics; however, he felt that using ICT was time consuming although he also thought that it will engage and motivate students to learn better. The teacher also strongly felt that student must be monitored while using ICT such as Internet browsing. His statement on ICT use in teaching can be noted from his responses:

> If we use ICT students will be better engaged and learn better but resources constraints, I try to use digital technologies whenever possible in my teaching students seek additional information on top of what they have learn in classrooms, I encourage research projects but lack of time and resources. I have not prepared a specific lesson using ICT in Physics but have used ICT as and when it was necessary and convenient. I do not use ICT always as it is time consuming and there are not enough facilities.

5.3.3.3 Importance to ICT

The teacher Sc16R04 considered ICT to be very important but at the same time he also thought use of ICT by students must be monitored. He proposed that if a proper monitoring is not carried students will land up getting unwanted information from the Internet. He said that ICT is a necessity in this 21st century and can contribute to the development of a nation but repeatedly mentioned that students must be monitored what they learn using ICT. His perceptions on the importance of ICT can be summarised in his words:

> In this 21st century students will learn better if we use ICT. Teaching will become easy but tough preparation. Sometimes I fear that if students are not monitored properly, they may land up in wrong ways but If we monitor properly students can contribute to nation building.

5.3.3.4 Resources

From the responses gathered, teacher Sc16R04 clearly showed that he was not able to use ICT in his teaching due to lack of resources. While he saw a potential in going paperless idea incorporating technologies and wanted to encourage his students to seek additional information using ICT, he was disappointed that there were insufficient ICT resources in the school. He stated:

> If we use ICT students will be better engaged and learn better but resources constraints. I encourage research projects but lack of time and resources. I am not able to use ICT always as it is time consuming and not enough facilities.

5.3.4 Students focus group analysis (Group Sc16R04#G02)

The student interview Sc16R04#G02 belonging to teacher Sc16R04 was conducted in one of science laboratory within the school premises. A total of five students (three boys and two girls) from Year 9 participated in the interview. The teacher Sc16R04 taught Physics for them. To provide confidence and confidentiality to the students, the teacher in consideration was not allowed during the conduct of interview, only the researcher and students were present throughout the interview. The information obtained from the student interview is summarised in Table 5.7. Like the teacher interview, the information was analysed by identifying the key

points that were relevant to the scope of study. These key points were then used to link with the teacher's information to arrive to a conclusion.

Table 5.7

Interview records (Students-Sc16R04#G02)

Interview records and analysis for students Sc16R04#G02				
	How often do you use ICT in your class?	**Themes/Analysis**		
		ICT use in Classroom	**ICT use outside the classroom**	**School Resources**
Question 1	During presentation times we use projectors.			
	Use mobiles to call their parents.			
	Use computers to find meanings for words in English and in IT class.			
	Once or twice in a week.			
	During break times we can go to computer lab anytime.			
Question 2	**Give some examples of activities carried out using ICT/computers?**			
Responses	Preparing presentation in IT class.			
	Projectors used in explaining diagrams in Biology.			
	Gather information from Internet for science exhibition.			
Question 3	**Do you have opportunities to interact with ICT in your science classroom?**			
Responses	Students can access Pisa tests questions from the computers.			
	Could access information on Pisa tests. Twice in a week. Created a Facebook account.			
Question 4	**Give some examples of ICT that you are confident in your learning?**			
	We are confident 50-60% to use the ICT.			

	Some of the skills were learned outside the classroom, some from teachers and self-learning.			
Question 5	**According to you what is the ICT status of your school?**			
	Our school has enough ICT facilities and skilled teachers. But we are not allowed to browse Internet.			

5.3.4.1 Discussion on students focus group (Sc16R04#G02)

The findings from students' group Sc16R04#G02 belonging to teacher Sc16R04 showed that ICT was used in classroom once or twice in a week. Students have used ICT to obtain information for their science exhibition and for class presentation. They also gathered information to do their PISA tests. One of the students created his social networking account using ICT. It was also found that students learned ICT skills equally from their teachers and from parents and relatives. Students agreed that they have enough ICT resources but mentioned that they were restricted to use Internet. Student Jerjer said, *"Our school has enough ICT facilities and skilled teachers, but we are not allowed to browse Internet".*

5.3.5 Conclusion

The teacher Sc16R04, a Physics teacher from school Sc16 was observed to possess high level of ICT skills and used ICT frequently in his teaching. He raised a concern of not having resources and having to spend a lot more time when using ICT. Information gathered from student's interview also indicated that while ICT was used by the teacher, it was not subject specific. He was eager to share his knowledge among his colleagues and use ICT in his teaching. Students, on the other hand had a different opinion, they mentioned that the school had enough ICT resources although Internet facilities was unavailable. The teacher was an active user of ICT. He used ICT in his teachings once in a week, exhibited high level of interest and confidence to use ICT. He also appeared to possess a strong knowledge on TPACK.

5.4 Case 3: School Sc19

School Sc19 was a middle secondary school located on the outskirt of the capital city, Thimphu. The school was established in the late 2000s and currently has more than 700 students and 36

teachers. The school provides education from Year 7 to Year 10. The school has one computer laboratory equipped with Internet connections.

5.4.1 Teacher Sc19R03 background

The participant Sc19R03 was a Biology teacher teaching in Year 9 and Year 10. The participant details including his mean scores are summarised in Table 5.8. From the table, the mean for use of ICT in daily life was 3.27 representing "Frequently or Once in a Week". The mean for interest to use ICT was 3.00 representing "Interested". His mean for level of confidence was 2.85 showing "Somewhat Confident". His mean for ICT uses in science teaching was 3.00 representing a use of "Once in a Week". The mean for importance of ICT was 2.83 representing "Moderately Important". He scored 90.00 out of 110 in TPACK score. This TPACK score represented "High Level" of TPACK.

Table 5.8

Quantitative results (Teacher Sc19R03)

ID	Demographic		ICT scores (mean/sum)					
Sc19R03	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	30+	Male	3.27	3.00	2.85	3.00	2.83	90.00

5.4.2 Interview analysis (Teacher Sc19R03)

A face to face interview was conducted with the teacher participant within the school campus. A conference room was used for interview. The information gathered was processed as described in section 5.1. Table 5.9 provides details of teacher Sc19R03 interview records.

Table 5.9

Interview records (Teacher Sc19R03)

Interview records and analysis for teacher Sc19R03					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**

Responses	ICT has become imperative in this century without which teaching learning will not work properly.				
	ICT is found to effective especially in preparation of lessons.				
	Mostly for preparing lessons and in delivery of my lessons.				
	Use ICT to get resources for preparation and obtain teaching materials from other schools and download materials.				
	Though we have constraints with resources and time, but we use projectors and PowerPoint, at least two times in a month.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Focusing on the delivery of lessons using ICT.				
Question 3	**What is the value in having your students use a computer?**				
Responses	With advancement in technology students must know how to use ICT.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	It fits well in subjects like Biology. I use mostly animated movies to teach my lessons.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	Most of the work and planning are done by IT department so less involvement.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	We share information that we get from the Internet.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	To be frank due to time constraints I am not able to use daily.				

	I mainly use PowerPoint to deliver a lesson, at the max two times in a month in my subjects.				
	But I use about three times in a week for my assessment and to prepare a lesson.				
	For students, it depends, many students have mobile with internet, and they use it on daily basis.				
	I encourage them to use it as it is the need of the times.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	ICT can be used for Concept mapping strategies and Lecture method.				
Question 9	**What activities have you used computers for in this academic term?**				
Responses	The recent one that I used was worksheet I developed a worksheet for students and provided assignments to students.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	Used similar worksheet last year as well.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	Yes, I did in project works and used ICT to assess it				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
	With respects to students, they use to get information. Often students ask teachers to use computers.				
Responses	With the society I think ICT is used more for communication.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
	Due to lack of resources, teacher is limited to browsing and getting information.				

Responses	Video conferencing could be effective in future.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	I consider myself as guide to my students.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
	It is mostly me who decide what to teach using ICT.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
	I do have basic skills like how to use Spreadsheet and PowerPoint, but I need more skills.				
Responses	I learn from other colleagues through workshops.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I feel that by using ICT teaching becomes interactive.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	Lessons become interactive.				
	Easy to get information for students.				
	Too many information on web so we need to decide which is the best.				
	Would like to see more use of ICT in schools such as video conferencing in near future.				

5.4.3 Discussion on interview (Teacher Sc19R03)

This section reports on the findings based on the themes for the teacher Sc19R03. As mentioned in section 5.1, four themes were identified: teacher's level of confidence, use of ICT in teaching, importance attached to ICT and factors associated with resources.

5.4.3.1 Confidence/Skills

Teacher Sc19R03 possessed the necessary ICT skills that enabled him to utilise in his science teaching. He actively shared his knowledge and at the same time obtained new knowledge from his friends. He applied his ICT skills such as Spreadsheet and PowerPoint knowledge in his teaching although he mentioned he would like to learn more ICT skills. He said "We share information that we get from the Internet. I do have basic skills like how to use Spreadsheet and PowerPoint, but I need more skills".

5.4.3.2 Use in science teaching

Teacher Sc19R03 used ICT frequently in his teaching. According to him, ICT helped him better plan his lessons and in delivering them to his students. ICT also helped him get additional information from the websites and from other schools. He used projectors to present his lesson prepared using PowerPoint at least two times in a month. He also used downloaded animated videos to assist his Biology lessons. He created a worksheet and project work for his students using ICT. He utilised ICT to maintain students' assessment records too. His confidence/skills can be summarised in his words as follows:

> ICT is found to be effective especially in preparation of lessons and in delivery of my lessons. I use ICT to get resources for preparation and obtain teaching materials from other schools. Though we have constraints with resources and time, but I use projectors and PowerPoint, at least two times in a month. ICT fits well in subjects like Biology. I developed a worksheet for students and provided assignments to students. I provided project works and used ICT to assess it.

5.4.3.3 Importance to ICT

The teacher Sc19R03 attitude towards the importance of ICT was optimistic and encouraging. From his responses it can be constructed that he looked at ICT as a tool, which is crucial for his student's achievement in modern times. He reinforced repeatedly that students must know how to use ICT in this age of global technologies. He supported that ICT helped him made his teaching easy and interactive to learn. He wanted the government and schools to implement ICT resources such as video conferencing which according to him is the need of the hour that will have leaps of benefits in education. He mentioned:

ICT has become imperative in this century without which teaching learning will not work properly. With advancement in technology students must know how to use ICT. I feel that by using ICT teaching becomes interactive. I would like to see more use of ICT in schools such as video conferencing in near future.

5.4.3.4 Resources

From the responses gathered, teacher Sc19R03 used his ICT skills and knowledge to improve his teaching despite the constraints in available resources. According to him, he lacked enough resources and time to utilise ICT in his teaching. He mentioned, *"due to lack of resources, teacher is limited to browsing and getting information only. To be frank due to time constraints I am not able to use daily"*. There was a need to include more teachers to participate in school IT management and policy planning level as the teacher participant mentioned he had no role in the school IT planning process. He said, *"Most of the work and planning are done by IT department so less involvement".*

5.4.4 Students focus group analysis (Sc19R03#G03)

The student interview Sc19R03#G03 belonging to teacher Sc19R03 was conducted in a school conference room. ne of science laboratory within the school premises. A total of five students (three boys and two girls) from Year 9 participated in the interview. The teacher Sc19R03 taught Biology for them. To provide confidence and confidentiality to the students, the teacher in consideration was not allowed during the conduct of interview, only the researcher and students were present throughout the interview. The information obtained from the student interview is summarised in Table 5.10. Like the teacher interview, the information was analysed by identifying the key points that were relevant to the scope of study. These key points were then used to link with the teacher's information to arrive to a conclusion.

Table 5.10

Interview records (Students-Sc19R03#G03)

Interview records and analysis for students Sc19R03#G03				
Question 1	**How often do you use ICT in your class?**	**Themes/Analysis**		
		ICT use in Classroom	**ICT use outside the classroom**	**School Resources**

	Rarely.			
	In IT class every week.			
	We use Projectors, thumb drives.			
	Mobile phones are not allowed but allowed during cultural shows.			
	Teacher bring laptops in the classroom to show videos to teach.			
Question 2	**Give some examples of activities carried out using ICT/computers?**			
Responses	Used during presentation and in staging plays (dramas).			
	Used Projector to give background effects (visual and sound effects) in cultural programmes.			
	Conducted a presentation on disaster management using ICT.			
	Used Internet to browse information for science exhibition.			
	We did a biology project and got information from the Internet.			
	Learning from YouTube videos is more enjoyable than from textbooks in science.			
	Learn about human heart using Internet.			
	Learn dance steps using YouTube video and used to access Facebook.			
Question 3	**Do you have opportunities to interact with ICT in your science classroom?**			
Responses	We get quite often to use Internet as these days as cultural show is going on.			
	Computers are free to use but many students are not interested.			
Question 4	**Give some examples of ICT that you are confident in your learning?**			

Responses	We are confident in using social networking apps (WeChat, Facebook, Google, Microsoft words, WhatsApp).			
	For me someone taught me these skills.			
	For me I learned myself on my own.			
	Sometimes we learn from our teacher.			
	We also learn from our friends.			
Question 5	**According to you what is the ICT status of your school?**			
Responses	We have enough ICT resources in our school.			
	Teachers are highly skilled and competent in using ICT.			

5.4.4.1 Discussion on students focus group (Sc19R03#G03)

The analysis of interview records from students' group Sc19R03#G03 belonging to teacher Sc19R03 revealed that ICT was used in learning areas but not specific to science education. While students mentioned that they used ICT such as Internet and projectors, it was mainly for other purposes such as for creating sound and visual effects during cultural programs in school. Student Khandhi mentioned, *"Used Projector to give background effects (visual and sound effects) in cultural programs"*.

However, there were also instances of teacher using laptops in classrooms to aid his teaching. student Dawa said, *"Teacher bring laptops in the classroom to show videos to teach"*. Similarly, another student Buzang said, "*I used Internet to browse information for science exhibition. We did a biology project and got information from the Internet"*.
Students appeared to be confident in using the basics ICT skills including the social networking applications as they stated, *"We are confident in using social networking apps" (WeChat, Facebook, Google, Microsoft words, WhatsApp)*. Students learned these skills mostly outside the classrooms but also showed teacher was involved in gaining their skills.

According to them, they had sufficient resources available in their schools and they thought that their teachers were competent, but students were not utilising these resources. One them stated, *"Computers are free to use, but many students are not interested"*.

5.4.5 Conclusion

The teacher Sc19R03, a Biology teacher from school Sc19 was an active user of ICT. He used ICT mainly in preparation of lessons, keeping assessment records and in delivering the lessons. He also used ICT to create assignments for his students. He had positive perceptions towards ICT use, and he emphasised on the importance of ICT in science education in this digital world. The teacher complained of not having enough time and resources to use ICT in his teaching. But students mentioned that the school had enough resources which was contradicting to teacher response. Perhaps, the teacher was raising concern with time rather than the resources. Overall, he possessed adequate skills and was found to be highly interested in using ICT in his teaching. The findings from the interview analysis supported his quantitative results.

5.5 Case 4: School Sc01

School Sc01 was a senior secondary school (central school) located in the central part of the country. The school was established in the mid-2000. Currently the school caters to about more than 700 students with about 38 teaching faculty. The school provides education form Year 7 to Year 12. The school had two rooms dedicated IT with Internet connection.

5.5.1 Teacher Sc01R01 background

The participant Sc01R01 was a Biology teacher. She taught general science in Year 7 and Biology in Year 9. The participant details including mean scores are summarised in Table 5.11. The mean for use of ICT in daily life was 3.62 representing "Frequently or Once in a Week". The mean for interest to use ICT was 3.77 representing "Interested". Her mean for level of confidence was 3.46 showing "Confident". Her mean for ICT uses in science teaching was 3.38 representing a use of "Once in a Week". The mean for importance of ICT was 2.77 representing "Moderately Important". She scored 98.00 out of 110 in TPACK score. This TPACK score represented an "High Level" of TPACK.

Table 5.11

Quantitative results (Teacher Sc01R01)

ID	Demographic		ICT scores (mean/sum)					
Sc01R01								
	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	30+	Female	3.62	3.77	3.46	3.38	2.77	98.00

5.5.2 Interview analysis (Teacher Sc01R01)

An online face to face interview was conducted with the teacher participant using a Facebook Messenger. Proper arrangements were made to simulate a real situation. Prior consent was obtained to determine an appropriate time. The information gathered was processed as described in section 5.1. Table 5.12 provides details of teacher Sc01R01 interview records.

Table 5.12

Interview records (Teacher Sc01R01)

Interview records and analysis for teacher Sc01R01					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	When time permits, I use ICT to disseminate ideas and give video lessons.				
	For collaborative learnings and communication among the students.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Exploring resources other than what is given in textbooks.				
	To obtain supplementary information from the Internet.				
	inquiry-based learning.				
Question 3	**What is the value in having your students use a computer?**				
Responses	I find that we can encourage student centred learning.				

	Increases motivation of learners and they learn teamwork values.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	ICT makes teaching easier especially in teaching science concepts.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
	We don't have an IT committee; IT teachers and assistants manage the IT resources.				
Responses	We put proposals to school management for planning and implementation.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	We share videos lessons and PowerPoint lessons.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	Frequently, maybe more than two times in a week.				
	Focus on presentations using Projectors.				
	School has three conference rooms and two IT rooms with projectors.				
	Students can access IT facilities as and when teachers decide to use IT rooms.				
	Less opportunity for students to work independently.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	inquiry based, collaborative learning and Project based learning.				
Question 9	**What activities have you used computers for in this academic term?**				
Responses	I took my students to IT lab to search information using Google from Internet.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				

Responses	Last year I used mostly video lessons and PowerPoint presentations.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	Most are Ungraded work and not included in assessment except project works.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	In my opinion, if we use ICT positively then it will encourage collaborative learning.				
	We must guide and can create a positive atmosphere for students.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	If it is used effectively it will enhance collaboration among teachers and students.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	As a guide				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	In Bhutanese classroom scenario, it is decided by teachers and have no rooms from students to make decisions.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I use almost all the basics ICT tools, but ICT is not common in our teaching system due to limited resources, so we need to update ourselves.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	When we compare mode of teaching using chalk and board and ICT, we can see a vast				

	difference in the learning outcomes in students.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	As of now teachers dominate use of ICT over the students and students are simply observers.				
	We should provide more opportunity to students to make them active learners.				
	Rather than just getting information, we must create online platforms/forums where students can express themselves.				

5.5.3 Discussion on interview (Teacher Sc01R01)

This section reports on the findings based on the themes for the teacher Sc01R01. As mentioned in section 5.1, four themes were identified: teacher's level of confidence, use of ICT in teaching, importance attached to ICT and factors associated with resources.

5.5.3.1 Confidence/Skills

From the analysis of interview records for teacher Sc01R01, it has been shown that she was confident in using almost all the basic ICT tools. She participated actively in learning communities and shared resources among teacher's colleagues. She used ICT for different teaching strategies such as inquiry-based learning and collaborative learning. She also frequently used videos and PowerPoint slides to aid her teaching. She stated, "*I use almost all the basics ICT tools, but ICT is not common in our teaching system due to limited resources, so we need to update ourselves".*

5.5.3.2 Use in science teaching

Teacher Sc01R01 was found to be using ICT with her teaching twice in a week. She used ICT mainly to disseminate ideas, exploring online materials to obtain supplementary information in addition to textbooks. She mentioned, *"When time permits, I use ICT to disseminate ideas and give video lessons. I use it for collaborative learnings and communication among the students, to explore resources and to obtain supplementary information other than what is given in textbooks".*

She used ICT to deliver teaching science concepts and to encourage student centred learning. According to her: *"ICT makes teaching easier especially in teaching science concepts and more student cantered".* She mostly used videos and PowerPoint slides in her teaching. While she involved her students to seek information from the Internet using Google, she also mentioned that students have less opportunity to work independently as teacher dominates when and how to use ICT. She utilised ICT to assess her students work particularly the project works. According to her, *"In Bhutanese classrooms, the use of ICT is decided by teachers and students have no rooms to make decisions and they are simply observers".*

5.5.3.3 Importance to ICT

Analysis of interview for teacher Sc01R01 revealed that she considered ICT to be very important in science teaching. She perceived that ICT motivated students and promoted values such as teamwork and effective communications. She said, "*ICT increases motivation of learners and they learn teamwork values, I find that ICT can encourage student centred learning and can be used for collaborative learnings and communication among the students".*

She stated that ICT was useful in conveying scientific concepts using various teaching strategies. According to her, the learning outcomes were far better when ICT is used compared to traditional chalk and board methods. She said, *"When we compare mode of teaching using chalk and board and using ICT, we can see a vast difference in the learning outcomes in students".*

She suggested that students should be given more opportunity to participate in decision making process and in the use of ICT. In addition, she thought that creating online forums will give access for students to express their views openly. She stated, *"We should provide more opportunity to students to make them active learners, rather than just getting information, we must create online platforms/forums where students can express themselves".*

5.5.3.4 Resources

From the interview records, it can be summarised that the teacher Sc01R01 had enough ICT facilities in her school. However, it was learned that the school had no IT committee to oversee planning and implementations related to ICT at school level. She said, *"we don't have an IT committee, IT teachers and assistants manage the IT resources"*. The teacher raised her

concern on having limited resources in teaching system, which she supposed was not having avenues for her to learn ICT skills provided by the system, but she mentioned that she was updating her knowledge on her own interests. She mentioned: *"I use almost all the basics ICT tools, but ICT is not common in our teaching system due to limited resources, so we need to update ourselves"*.

5.5.4 Conclusion

The teacher Sc01R01, a Biology teacher from school Sc01 constantly used ICT in her teaching. The teacher used ICT twice in a week. She was found to be confident in using standard ICT tools. She mainly used ICT to gather additional information and in conducting project works with her students. Videos and PowerPoint slides were some of the main ICT tools utilised by the teachers. She considered ICT very important and thought crucial in bringing changes to learning outcomes but at the same time she was concerned about limited ICT inclusions in the overall education system.

5.6 Case 5: School Sc24

School Sc24 was a middle secondary school (now central school) located in the central part of the country. The school was established in the late 90s. Currently the school has more than 750 students with about 30 teachers. The school provides education from Year 7 to Year 10. The school had one computer laboratory with Internet connection.

5.6.1 Teacher Sc24R01 background

The participant Sc24R01 taught Biology and Chemistry in Year 9 and Year 10. Table 5.13 provides quantitative results of Sc24R01. The mean for use of ICT in daily life was 3.38 representing "Frequently or Once in a Week". The mean for interest to use ICT was 3.38 representing "Interested". His mean for level of confidence was 3.23 showing "Confident". His mean for ICT use in science teaching was 3.31 representing a use of "Once in a Week". The mean for importance of ICT was 3.38 representing "Important". He scored 79.00 out of 110 in TPACK score. This TPACK score represented an "Average Level" of TPACK.

Table 5.13

Quantitative results (Teacher Sc24R01)

ID	Demographic		ICT scores (mean/sum)					
Sc24R01	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	30+	Male	3.38	3.38	3.23	3.31	3.38	79.00

5.6.2 Interview analysis (Teacher Sc24R01)

Interview with teacher Sc24R01 was conducted using a Facebook Messenger. Prior consent and proper arrangements were made with the teacher to ensure that a quality data was gathered. The information gathered was processed as described in section 5.1. Table 5.14 provides details of teacher Sc24R01 interview records.

Table 5.14

Interview records (Teacher Sc24R01)

Interview records and analysis for teacher Sc24R01					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	To give exposure to students as they learn more than book knowledge.				
	From online class they learn new things. It is a visual mode of learning. Supplement on the lessons taught in the class.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Relate basic knowledge to practical life as organic farming practices.				
	Videos on digestive system in Biology.				
	Knowledge and applications.				
Question 3	**What is the value in having your students use a computer?**				

Responses	They learn to place more values on the topics learned as the learning is a visual mode.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	In general ICT fits well with science especially subjects like Biology. With chemistry to certain extent.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	I am the secretary for examination committee, and I help in making result sheets.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	I download clips on topics and share with my teacher colleagues.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	If we have enough projectors, we can use ICT in daily basis, but we have only one projector. Many teachers want to take class using projectors.				
	Two times in week based on lessons.				
	Students don't get much time to get ICT unless they have free times and lab is free.				
	Only one IT lab and it is always packed with normal class.				
	Students hardly get time to use ICT.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	inquiry-based learning which is applicable in Biology lessons. Simulation in Physics. Concept mapping model.				
Question 9	**What activities have you used computers for in this academic term?**				

Responses	Simulation lessons. Online clips to teach working of different organ systems in biology.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	Provided action research topics to students.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	I have assessed work with ICT. Assessment was included in the overall assessment.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	Students learn to participate at global level such as awareness in global warming				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	With video clips and online materials students learn better and we can save time. Over the years, I can see the changes ICT has brought into science education. A big move in innovations.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	As a guide and let students explore.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	It is mostly the teacher but occasionally I ask for their opinion.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I need more skills. We should always be in touch with ICT if not we tend to forget. We need to have interests and learn ourselves.				

	Teachers should be provided refresher course in ICT like *Chiphen Rigphel* Program.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I feel satisfied when I use ICT and students are involved.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	They learn concepts better and they can apply the knowledge to day to day life.				
	Correlate textbook knowledge to real life situation and become more innovative.				
	Students may become too dependent on ICT and skills such as writing, and spellings might be jeopardised. They might neglect the basics etiquette or values associated with our country if ICT is used extensively.				

5.6.3 Discussion on interview (Teacher Sc24R01)

This section reports on the findings based on the themes for the teacher Sc24R01. As mentioned in section 5.1, four themes were identified: teacher's level of confidence, use of ICT in teaching, importance attached to ICT and factors associated with resources.

5.6.3.1 Confidence/Skills

Teacher Sc24R01 was confident in using basic ICT tools such as browsing Internet and downloading videos clips. He used Spreadsheet knowledge for students' result analysis, which he shared with other teacher colleagues. According to him, he is eager to acquire new ICT skills. He felt that self-interest and updating oneself is necessary to obtain new ICT knowledge. He stated, *"I need more skills. We should always be in touch with ICT if not we tend to forget. We need to have interests and learn ourselves. Teachers should be provided refresher course in ICT like Chiphen Rigphel Program".*

5.6.3.2 Use in science teaching

Teacher Sc24R01 used ICT twice in a week. His use of ICT was determined by the type of lessons he taught. He used ICT to supplement his teaching and to provide additional information through video clips. He applied enquiry-based, simulation and concept mapping strategies using ICT. He also provided assignment for his students to be completed using online materials. He had assessed his student work using ICT and was included in the overall assessment. According to him, students learn better when ICT was used, and he had seen positive changes ICT has brought in science education over the years. He mentioned, "*With video clips and online materials students learn better and we can save time. Over the years, I can see the changes ICT has brought into science education. A big move in innovations".*

5.6.3.3 Importance to ICT

Teacher Sc24R01 perceived ICT important to correlate classroom learning into real life situation. He considered ICT important for providing exposure to his students and gather additional information apart from the textbooks. Since ICT provides a visual mode of learning, students learned better and valued lessons more as compared to lessons taught without ICT. However, he thought that extensive use of ICT might make students too dependent on online information and may deteriorate handwriting skills and grammatical knowledge. He also had a concern over students neglecting basics cultural norms and values if ICT dominates teaching. According to him:

> ICT is important to give exposure to students as they learn more than book knowledge. To correlate textbook knowledge to real life situation and become more innovative. Students may become too dependent on ICT and skills such as writing, and spellings might be jeopardised. They might neglect the basics etiquette or values associated with our country if ICT is used extensively.

5.6.3.4 Resources

From the interview records, it was clear that teacher Sc24R01 had limited access to ICT resources thereby limiting his use of ICT in science teaching. According to him teachers are eager to use projectors in their teachings, but they have only one It room and only one projector in the school. He mentioned:

> If we have enough projectors, we can use ICT in daily basis, but we have only one projector. Many teachers want to take class using projectors. Only one IT lab and it is always packed with normal class. Students hardly get time to use ICT.

5.6.4 Conclusion

Teacher Sc24R01 was confident in browsing Internet and downloading videos clips. He used Spreadsheet knowledge for students' result analysis and felt that it was necessary to update ICT knowledge and needs support from the government in receiving refresher course such as teacher development program like Chiphen Rigphel. He used ICT twice a week and applied various teaching strategies. According to him ICT provided a visual mode of learning and made students learn better. Too much dependence on ICT might undermine student's ability learn handwriting skills and grammar besides neglecting cultural values. He clearly indicated that he had limitations in using ICT in his teaching due to unavailability of resources.

5.7 Case 6: School Sc25

School Sc25 was a middle secondary school located in the eastern part of the country. The school was established in the early 70s. Currently the school has more than 800 students with about 36 teachers. The school provides education from Year 7 to Year 10. The school has one computer laboratory with Internet connection.

5.7.1 Teacher Sc25R02 background

The participant Sc24R02 taught Chemistry in Year 9 and Year 10. Table 5.15 provides quantitative results of Sc25R02. The mean for use of ICT in daily life was 2.85 representing "Rarely or Once a Month". The mean for interest to use ICT was 3.38 representing "Interested". Her mean for level of confidence was 2.92 showing "Somewhat Confident". Her mean for ICT use in science teaching was 3.08 representing a use of "Once in a Week". The mean for importance of ICT was 3.31 representing "Important". She scored 71.00 out of 110 in TPACK score. This TPACK score represented an "Average Level" of TPACK.

Table 5.15

Quantitative results (Teacher Sc25R02)

ID	Demographic		ICT scores (mean/sum)					
Sc25R02	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	30+	Female	2.85	3.38	2.92	3.08	3.31	71.00

5.7.2 Interview analysis (Teacher Sc25R02)

Interview with teacher Sc25R02 was conducted using a Facebook Messenger. Prior consent and proper arrangements were made with the teacher to ensure that a quality data was gathered. The information gathered was processed as described in section 5.1. Table 5.16 provides details of teacher Sc25R02 interview records.

Table 5.16

Interview records (Teacher Sc25R02)

Interview records and analysis for teacher Sc25R02					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	To add variety to teaching strategies.				
	Cater to technological needs of students and to introduce then to digital world.				
	To shift from a teacher centred to student centred learning.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Use it for my routine tasks such as lesson planning, record maintaining, browsing information (downloading videos and images).				
Question 3	**What is the value in having your students using ICT?**				
	Students do not have access to ICT resources.				

Responses	It motivates them and introduces them into digital world.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	Provided the facilities are available ICT fits well.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	When it comes to planning, we discuss and give suggestions and recommendations to school authority.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	We share among teachers and students. We also receive help from Dzongkhag ICT officer.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	Alost every day for lesson planning and keeping records.				
	Students have no access with ICT in science subjects, but they use computers three times in a week in IT class.				
	One computer per two students.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	I use it for demonstration and lecture and simulation and modelling. To understand abstract and difficult lessons By download videos and images.				
Question 9	**What activities have you used computers for in this academic term?**				
Responses	Recently I used it for science exhibition.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				

Responses	Make a working model for a science exhibition.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	No formal assessment using ICT.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	The skills and knowledge that students learn in school will have a direct impact on how ICT used in the society.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	It has great potential to explore new areas which is not covered by traditional method. Learning and teaching process will be livelier.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	Teachers still plays a dominant figure student are passive learners.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	Most of times it is the teacher who decide when to use ICT.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I have the basics skills to use ICT, I have studied IT as a subject when I was trainee. Whenever I encounter, I get help from others and use Google.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I feel handy and appropriate to use. Students feel interested when ICT is integrated to teaching when using videos etc.				

Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	No ICT resources to solve technical issues encountered.				
	No proper Infrastructure and no stable Internet connections.				
	Teachers are not fully equipped, and they are not ready to integrate ICT in their teaching.				

5.7.3 Discussion on interview (Teacher Sc25R02)

This section reports the findings from the interview analysis of teacher Sc25R02. As mentioned in section 5.1, four themes were identified: teacher's level of confidence; use of ICT in teaching; importance attached to ICT, and factors associated with resources.

5.7.3.1 Confidence/Skills

Teacher Sc25R02 possessed the basic ICT skills. She was involved in planning and implementation of ICT policies at the school level. She shared ICT resources such as video clips and images with her colleagues. According to her, ICT was an appropriate tool and she was able to integrate well in her teaching. She mentioned:

> When it comes to planning, we discuss and give suggestions and recommendations to school authority. We share among teachers and students. I have the basics skills to use ICT, I have studied IT as a subject when I was trainee. Whenever I encounter problems, I get help from others and use Google search engines.

5.7.3.2 Use in science teaching

According to teacher Sc25R02, she claimed to use ICT almost every day to conduct her routine tasks as a teacher, such as lesson planning, downloading videos, obtaining online information and for keeping records. Her quantitative results showed that she use ICT once in a week in her teaching. ICT was mainly used to convey difficult lessons and abstract ideas to students. ICT also provided her to add variety to her teaching strategies and helped her to achieve student centred approach. Her recent use with her students was for science exhibition. According to

her, teachers dominates over the decision to use or not to use ICT and students act as a passive learner. She stated:

> I use ICT to add variety to teaching strategies. To shift from a teacher centred to student centred learning. I use it almost every day for my routine tasks such as lesson planning, record maintaining, browsing information (downloading videos and images). Recently I used it for science exhibition. Teachers still plays a dominant figure student are passive learners. Most of times it is the teacher who decide when to use ICT.

5.7.3.3 Importance to ICT

Teacher Sc25R02 considered ICT as an essential tool that will help to change from a teacher-centred learning to a student-centred learning. She mentioned that ICT is necessary to motivate students' learning and to introduce them to a digital world. According to her, ICT can help explore new areas which are not covered by traditional way of teaching, the way in which students use ICT could have a direct impact on the society. She stated:

> ICT cater to technological needs of students and to introduce then to digital world. ICT is important to shift from a teacher-centred to student-centred learning. The skills and knowledge that students learn in school will have a direct impact on how ICT used in the society. It has great potential to explore new areas, which is not covered by traditional method.

5.7.3.4 Resources

From the interview records, teacher Sc25R02 appeared to have constant access to ICT resources but she complained of students not having access to ICT resources. She specifically mentioned about not having an expertise to solve technical issues encountered while using ICT although she also responded that she sought help from an ICT officer from the district administration. She raised her concerns of not having a stable Internet connection. According to her, these lack resources was hindering teacher's ability to integrate ICT in science teaching. she said,

> Students do not have access to ICT resources. No ICT resources to solve technical issues encountered. No proper Infrastructure and no stable Internet

connections. Teachers are not fully equipped, and they are not ready to integrate ICT in their teaching.

5.7.4 Conclusion

Teacher Sc25R02 was confident in using basic ICT tools in her teaching. She utilised ICT such as Internet/Google to gather information to download videos and images to assist her teaching and browsing Internet and downloading videos clips. She constantly used ICT in her lesson planning and to teach abstract concepts to her students. ICT helped her to include diversity in her lessons and to achieve student-centred approach in her teaching. according to her, ICT plays an important role in motivating students and introducing them to a technological world. She had problems with technical issues associated with ICT and in instability of Internet connections in her school.

5.8 Case 7: School Sc39

School Sc39 was a middle secondary school (Central School) located in the southern part of the country. The school was established in the late 90s. Currently the school has more than 800 students with about 39 teachers. The school provides education from Year 7 to Year 10. The school has one computer laboratory with Internet connection.

5.8.1 Teacher Sc39R03 background

The participant Sc39R03 taught Physics in Year 9 and Year 10. Table 5.17 provides quantitative results of Sc39R03. The mean for use of ICT in daily life was 3.15 representing "Frequently or Once in a Week". The mean for interest to use ICT was 3.62 representing "Interested". The mean for level of confidence was 3.62 showing "Confident". The mean for ICT use in science teaching was 3.23 representing a use of "Once in a Week". The mean for importance of ICT was 3.62 representing "Important". The teacher Sc25R03 scored 101 out of 110 in TPACK score. This TPACK score represented a "High Level" of TPACK.

Table 5.17

Quantitative results (Teacher Sc39R03)

ID	Demographic		ICT scores (mean/sum)					
Sc39R03	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	25+	Male	3.15	3.62	3.62	3.23	3.62	101.00

5.8.2 Interview analysis (Teacher Sc39R03)

Interview with teacher Sc39R03 was conducted using a Facebook Messenger. Prior consent and proper arrangements were made with the teacher to ensure that a quality data was gathered. The information gathered was processed as described in section 5.1. Table 5.18 provides details of teacher Sc39R03 interview records.

Table 5.18

Interview records (Teacher Sc39R03)

Interview records and analysis for teacher Sc39R03					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	Collect information for teaching learning purposes.				
	To provide extra knowledge beyond textbooks.				
	Download videos related topics.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Presentations in the classrooms. Students also use projectors to do presentations.				
Question 3	**What is the value in having your students using ICT?**				
Responses	Some of the values are value of sharing, teamwork, and cooperation.				
Question 4	**How does ICT fit into your teaching overall?**				

Responses	I can get necessary information from Internet for my teaching.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	I am not IT teacher, but we share videos and lessons with other teachers in my department.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	Present information to teachers and parents.				
Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	As a teacher I use every day in my personal life.				
	Students can use ICT based on the time allocated by the school.				
	I used ICT as and when it is demanded by lessons. I take laptop to my class too.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	I use ICT particularly in afternoon classes to motivate students and save time.				
Question 9	**What activities have you used computers for in this academic term?**				
Responses	I taught a lesson using a video clip.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	Based on the topics I have used ICT to teach.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				

Responses	I have assessed their presentations using ICT and was included the overall assessment.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	Students must be guided properly to use ICT in a correct manner.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	I see lots of potential; ICT can be very helpful to explain difficult topics.				
	Can Create more creativity and knowledge will be enhanced.				
Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	Facilitator and I guide them to right channel so that they don t misuse the ICT.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	Mostly determined by students and topics.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I am not an expert, but I did a basic ICT course of own interest. If Ministry could provide training to teacher our skills can be enhanced.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	I feel satisfied when I make my students understand after providing extra information.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	Danger of getting wrong information from the websites and they might misuse ICT.				

	Easy access to information for science teaching.				
	Lack of resources like projectors in our school.				
	We need further trainings so that we can implement ICT properly.				

5.8.3 Discussion on interview (Teacher Sc39R03)

This section reports the findings from the interview analysis of teacher Sc39R03. As mentioned in section 5.1, four themes were identified: teacher's level of confidence, use of ICT in teaching, importance attached to ICT and factors associated with resources.

5.8.3.1 Confidence/Skills

Teacher Sc39R03 claimed to use ICT daily in his personal life. The quantitative results showed that he was a frequent user of ICT in his daily life. He was confident in using Internet to obtain information related to the topics and download required videos. He undertook professional learning related to ICT at his own expense. He felt that the ministry of education should provide professional learning, so that teachers knowledge could be enhanced. He mentioned:

> As a teacher I use every day in my personal life, I am not an IT teacher, but we share videos and lessons with other teachers in my department. I have assessed student's presentations using ICT and was included in the overall assessment. I am not an expert, but I did a basic ICT course of own interest. If Ministry could provide training to teacher our skills can be enhanced.

5.8.3.2 Use in science teaching

Teacher Sc39R03 mostly used ICT to collect additional information, download videos and to provide extra knowledge beyond the textbooks. He taught the lessons using PowerPoint presentations both by using projectors and his personal laptops. His use of ICT was determined by the type of topics that he taught and often the time of the day he was in the class. According to him:

> I use ICT to collect information for teaching learning purposes, to provide extra knowledge beyond textbooks. I do presentations in the classrooms. My students also use projectors to do presentations. I used ICT as and when it is

> demanded by lessons. I take laptop to my class too. I use ICT particularly in afternoon classes to engage students and save time.

5.8.3.3 Importance to ICT

According to teacher Sc39R03, ICT greatly helped him to handle abstract and difficult topics. In addition, he felt that ICT fostered values such as teamwork and cooperation among students; It also can create avenues for students to learn extra knowledge and to become creative minds. For him, by using ICT he could easily obtain the required information needed for his teaching. However, he cautioned the danger ICT can bring upon students if they are not guided in a right manner. He stated:

> I can get necessary information from Internet for my teaching. ICT is an easy access to information for science teaching. I see lots of potential [and] ICT can be very helpful to explain difficult topics. Students must be guided properly to use ICT in a correct manner, as there is a danger of getting wrong information from the websites [or] they might misuse ICT.

5.8.3.4 Resources

From the interview records, teacher Sc39R03 appeared to have constant access to ICT resources including his own personal laptop, but he complained of not having enough projectors in his school. He mentioned that students could use ICT resources based on the schedule made by the school. According to him, there was a need for teachers to upgrade their ICT knowledge so that they can implement the ICT properly in their teaching. He stated:

> Students can use ICT based on the time allocated by the school. Lack of resources like projectors in our school. If the ministry could provide training to teacher our skills can be enhanced. We need further trainings so that we can implement ICT properly.

5.8.4 Conclusion

Teacher Sc39R03 was confident in using ICT such as personal laptop and Internet in obtaining additional information and to download videos. He utilised ICT such as projectors including his own personal laptop to teach his lessons in the classrooms. His main aim was to provide

extra information to his students besides the textbooks. ICT helped him to get information easily and to handle abstract and difficult topics in his teaching. He was worried that ICT might be misused by students and hence thought that proper guidance is essential. He raised concerns relating to lack of ICT resources in school and the support needed from the ministry to provide trainings for teachers to equipped them to integrate ICT effectively in teaching of science.

5.9 Case 8: School Sc05

School Sc05 was a middle secondary school located in the eastern part of the country. The school was established in the late 2000s. Currently the school has more than 860 students with about 41 teachers. The school provides education from Year 7 to Year 10. The school has one computer laboratory with Internet connection.

5.9.1 Teacher Sc05R01 background

The participant Sc05R01 taught Biology in Year 9 and Year 10. He was the IT teacher in the school. Table 5.19 provides quantitative results of Sc05R01. The mean for use of ICT in daily life was 3.46 representing "Frequently or Once in a Week". The mean for interest to use ICT was 3.92 representing "Interested". The mean for level of confidence was 3.00 showing "Confident". The mean for ICT use in science teaching was 3.08 representing a use of "Once in a Week". The mean for importance of ICT was 3.62 representing "Important". The teacher Sc05R01 scored 77 out of 110 in TPACK score. This TPACK score represented an "Average Level" of TPACK.

Table 5.19

Quantitative results (Teacher Sc05R01)

ID	**Demographic**		**ICT scores (mean/sum)**					
Sc05R01	Age	Gender	Daily use	Interest	Confidence	Use in teaching	Importance	TPACK score
	40+	Male	3.46	3.92	3.00	3.08	3.62	77.00

5.9.2 Interview analysis (Teacher Sc05R01)

Interview with teacher Sc05R01 was conducted using a Facebook Messenger. Prior consent and proper arrangements were made with the teacher to ensure that a quality data was gathered. The information gathered was processed as described in section 5.1. Table 5.20 provides details of teacher Sc05R01 interview records.

Table 5.20

Interview records (Teacher Sc05R01)

Interview records and analysis for teacher Sc05R01					
Question 1	**What are the main purposes you want to use ICT for with your students?**	**Themes/Analysis**			
		Confidence/ Skills	**Use in science teaching**	**Importance**	**Resources**
Responses	For interactive teaching learning process.				
	Provide variety of life skills and implementation day to day ICT life skills.				
	Hands on experience and practices with ICT.				
Question 2	**What are you focusing on now in the use of ICT?**				
Responses	Designing, animations and Keyboard shortcuts.				
Question 3	**What is the value in having your students using ICT?**				
Responses	Because of its usefulness students show genuine interest towards ICT. It is the need of the technological world.				
Question 4	**How does ICT fit into your teaching overall?**				
Responses	ICT goes well with my teaching. There is a mismatch of curriculum and use of ICT therefore it need re-evaluation.				
Question 5	**How do you contribute to school ICT planning? What would you like to contribute?**				
Responses	ICT planning and its use at student and teachers' level in the school.				
Question 6	**What involvement do you have with learning communities that use ICT?**				
Responses	Conducted school-based program to promote ICT at school level.				

Question 7	**Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?**				
Responses	Most of the times we use to plan lessons and maintain CA (continuous assessment)				
	Almost every time to maintain notes.				
	Students use for presentations and in group works.				
Question 8	**What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?**				
Responses	PowerPoint presentation, audio visual, quizzes and activity-based learning.				
Question 9	**What activities have you used computers for in this academic term?**				
Responses	Every day I use in maintaining lesson plans And keeping evidence-based records.				
Question 10	**To what tasks have you applied computers during the last term? How have you determined those tasks?**				
Responses	PowerPoint presentations and to improve previous lessons plans and slides.				
Question 11	**Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?**				
Responses	Yes, we include in their CA.				
Question 12	**In what ways do you connect what the students do with ICT and the way ICT is used in our society?**				
Responses	We got to guide them properly so that they know how to use when they are outside the school premises.				
Question 13	**What potential do you see for ICT to support learning and teaching processes with your class?**				
Responses	We can do enquiry-based learning, easy access to information and with ICT teaching learning becomes interesting.				
	Foster creativity and critical thinking and boost the learning of science.				

Question 14	**What do you see as your main roles when using ICT with your classes? What roles do the students have?**				
Responses	To promote interactive teaching, learning by doing. Facilitate and encourage to use modern technologies.				
Question 15	**In what ways are students permitted to contribute to decisions about the use of ICT?**				
Responses	They enjoy using ICT, I listen to my students as well sometimes.				
Question 16	**What skills do you have in using ICT and what steps do you take to develop the skills you need?**				
Responses	I can use the Internet to update and give new information to students. We need to keep ourselves up to date else we become obsolete.				
Question 17	**How do you feel when you use a computer and when you support your students in using computers?**				
Responses	It is encouraging when we meet our goals. We explore beyond the classroom.				
Question 18	**What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?**				
Responses	We need to update the current resources. Need more resources.				
	Encourage teachers and students to use ICT more often.				
	Encourage schools to create online system for assessing students' works.				
	Proper monitoring is needed so that they understand the proper use of ICT particularly social networking sites.				

5.9.3 Discussion on interview (Teacher Sc05R01)

This section reports the findings from the interview analysis of teacher Sc05R01. As mentioned in section 5.1, four themes were identified: teacher's level of confidence; use of ICT in teaching; importance attached to ICT, and factors associated with resources.

5.9.3.1 Confidence/Skills

Teacher Sc05R01 was confident in using basic ICT tools such as PowerPoint, Projectors, Microsoft words, Spreadsheet and Internet. He constantly used ICT to plan his lessons and to maintain records for his students. He used PowerPoint presentations and conducted quizzes and school-based information program for teachers and parents. According to him, he was with constant touch with ICT to keep himself up to date with the technological changes. He stated:

> I use ICT for designing, animations and Keyboard shortcuts. I was involved in ICT planning and its use at student and teachers' level in the school. I conducted school-based program to promote ICT at school level. I used PowerPoint presentation, audio visual, quizzes and activity-based learning. I Facilitate and encourage students to use modern technologies. I can use the Internet to update and give new information to students. We need to keep ourselves up to date else we become obsolete.

5.9.3.2 Use in science teaching

Teacher Sc05R01 mostly used ICT to gather information specifically to plan lessons and maintaining CA records of students. According to him ICT helped him make his teaching learning process more interactive and provided students hands on experiences. He used variety of activities such as PowerPoint presentations, quizzes and activity-based learning. He shared his concern that the current curriculum was not ICT friendly and needs re-evaluation so that ICT can be integrated effectively into the existing science curriculum. He mentioned:

> ICT makes teaching learning process more interactive. I use ICT every day in maintaining lesson plans and CA. We can do enquiry-based learning, ICT is an easy access to information and with ICT teaching learning becomes interesting. There is a mismatch of curriculum and use of ICT therefore it need re-evaluation.

5.9.3.3 Importance to ICT

Teacher Sc05R01 thought ICT was essential in providing variety of life skills to students. The usefulness and essence of ICT was demonstrated from the manner's students adhere importance and interest to learn ICT. According to him, ICT can foster creativity, critical thinking and enhance science learning. However, he was concerned that students might misuse ICT and they can be victimised. Therefore, proper guidance and monitoring was required so that students use the ICT in an appropriate manner. He mentioned:

> ICT provides variety of life skills and foster creativity and critical thinking and boost the learning of science. Because of its usefulness, students show genuine interest towards ICT. It is the need of the technological world. Proper monitoring is needed so that they understand the proper use of ICT particularly social networking sites.

5.9.3.4 Resources

Teacher Sc05R01 appeared to have constant access to ICT resources but he raised concern relating to not having enough resources. According to him, there was a need to update and expand the existing ICT resources in the school. He also felt that there was a lack of interests and motivation among teachers and students to utilise ICT. He believed that school should create teaching resources such as online system for conducting assessment of students' tasks. He stated: *"We need to update and expand the current ICT resources, encourage teachers and students to use ICT more often. School needs to create online system for assessing students' works".*

5.9.4 Conclusion

Teacher Sc05R01 confidently used PowerPoint, Projectors, Microsoft words, Spreadsheet and Internet. He constantly used ICT to plan his lessons, maintain records, conduct presentations and quizzes. According to teacher Sc05R01, ICT helped him make his teaching learning process more interactive and provided students hands on experiences. ICT was essential in providing variety of life skills to students, fostering creativity and critical thinking. Students also adhered importance and interest to learn as it is the need of this technological world. He was concerned of not having enough ICT resources and suggested that there was a need to

motivate and encourage teachers and students to use ICT more often in their teaching learning processes.

5.10 Summary

A total of eight middle secondary science teachers participated in the interview and three groups of students belonging to these teachers participated in focus group discussion. Analysis of the interview and focus group records indicated that most of these teachers and students exhibited their interests to use ICT in their teaching learning process. Almost all the respondents including the students stated that there were limited ICT resources in the schools for them to utilise effectively in the learning process.

CHAPTER 6: DISCUSSION AND CONCLUSION

ICT has become an inevitable aspect of globalisation. The potentiality offered by ICT especially in the field of education is being recognised all over the world and teachers play a crucial role in implementing the benefits associated with ICT. The way ICT is used in teaching and learning process is determined largely by the skills, interest, confidence, perceptions, resources and ICT knowledge possessed by teachers. Often a combination of these factors is necessary for proper integration of ICT in education. Foreseeing the benefits ICT can bring to the country, and like many other countries, Bhutan has given priority to development of ICT and its related infrastructure over the recent years. Much importance and focus has been given to impart ICT knowledge to the public as well as the education system. Nationwide program such as Chiphen Rigphel has been a successful achievement in the areas of improving ICT among the Bhutanese society.

Importantly, there appears to be limited, or little if any, research conducted relating to use of ICT in Bhutanese schools. While there existed some studies that investigated ICT usage, there are no comprehensive study conducted so far in order to understand the general trends of ICT use among science teachers in Bhutan. Therefore, this current study investigated the general patterns of ICT use in middle secondary schools in the Himalayan Kingdom of Bhutan. A total of 162 middle secondary science teachers participated in the quantitative phase of the study. Out of the survey participants, eight teachers and three groups of students also participated in the qualitative phase. The research tried to find answers to the following questions:

1. What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?
2. What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan?
3. What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms?
4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

To address the above research questions, a mixed method design was employed to collect data. The quantitative phase involved conducting survey with 162 middle secondary science teachers from various part of the Bhutan. The qualitative phase involved interviewing eight teachers and three groups of students. The questionnaire for the quantitative data collection was designed in such a way to gather information relating to teachers' confidence/skills to use ICT; teachers' interest and use of ICT in science teaching; perceptions towards use of ICT and to measure the TPACK. The semi-structured interview questions were designed to obtain additional information on the quantitative data and to support the quantitative findings.

This first section discusses the main findings from both quantitative and qualitative analysis from the perspectives of the research questions. After summarising the findings, some limitations of this study are listed. Recommendations possible from the findings and implications for future research follow limitations. Finally, the overall conclusion from this study is given a to end this thesis report.

6.1 The Main Message of this Study

The main message from this study is that there is a huge potential for introduction of technology in middle secondary science education in Bhutan. The basis of this main message are the findings derivable from the results described in the previous chapter. Eight main findings have been obtained from the quantitative analysis of this study. They are as follows:

Finding #1: Majority (68%) of middle secondary science teachers in Bhutan possessed a computer with Internet connections.

Finding #2: Middle secondary science teachers of Bhutan used Mobile phones; Internet; Social Networking; Word processing, and Email communication daily or at least once a week. They rarely used E-journals, Databases or Web designing.

Finding #3: Middle secondary science teachers of Bhutan exhibited high level of interest to use Internet; Mobile phones; Word processing, and Social networking. They lacked interest to use Databases, E-journals and Web designing.

Finding #4: Middle secondary science teachers of Bhutan showed a high confidence level to use Mobile phones; Social networking; Internet; Word processing; Slideshow, and Email communication. They lacked the confidence to use Databases, E-journals and Web designing.

Finding#5: Middle secondary science teachers of Bhutan used Mobile phones and Internet once a week in their teaching. They least used Digital cameras, Databases, E-journals and Web designing.

Finding #6: Middle secondary science teachers of Bhutan considered the Internet; Mobile phones; Slideshow; Word processing, and Data projectors very important for science teaching. They considered Social networking and Web designing least important.

Finding #7: Most middle secondary science teachers of Bhutan demonstrated; competence in TPACK; the majority (47%) possessed "High Level", and (33%) possessed an "Average Level" of TPACK.

Finding #8: Lack of time; lack of resources, and the lack of skills, were the three main factors that affected the use of ICT by the middle secondary science teachers in Bhutan.

How these findings addressed the research questions, are examined in the following sections arranged in the order of research questions given in Chapter 1 and repeated at a few other places.

6.2 Research Question 1

What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?

Answers to this question can be explained from the main findings presented in section 6.1. The summary findings 2, 4, 5 and 7 clearly showed the level of ICT knowledge and skills possessed by the middle secondary science teachers. These key findings explored the use of ICT tools, confidence level, ICT use in science teaching and TPACK, all of which are associated to ICT knowledge and skills. Furthermore, supporting answer to this question comes from the answer to the interview question 16. This question was: What skills do you have in using ICT and what steps you take to develop the skills you need.

The answers varied from not an expert to basic skills in using certain applications. One teacher was ICT teacher and was an expert. Most of them perceived the need to be up to date in ICT knowledge and many of them wanted further training and refresher courses for this purpose. The teachers assessed their ICT skills reasonably and recognised the need to be up to date.

The types of variations in ICT skills of teachers in this study were similar to the findings from Greece reported by Vitanova et al. (2015) in which majority of them were proficient and a few teachers possessed low to moderate levels of ICT skills.

In the review of literature, we have seen that the effectiveness of teaching depends on how well the teachers use technology (Incantalupo et al., 2013). Siorenta and Jimoyiannis (2008) had found that the skills and attitudes of teachers affect the extent to which they use technology in schools. The existence of specific programmes for enhancing IT skills of teachers in Scotland and whole of UK was highlighted (Williams et al., 2000). The possibility of low levels of IT skills among teachers in developing countries could be visualised from the work of Buabeng-Andoh, (2012) in Ghana, Özdemir, (2017) in Turkey and Akarawang, Kidrakran, and Nuangchalerm (2015) in Thailand. Unless deliberate development programmes are undertaken at the national level, the situation will not improve.

The findings for answering the Research Question 1 are adequately supported by literature. Therefore, it can be concluded that this study has answered the first research question satisfactorily.

6.3 Research Question 2

What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan**?**

Finding#6 is direct answer to this research question. Middle secondary science teachers of Bhutan considered the Internet; Mobile phones; Slideshow; Word processing, and Data projectors very important for science teaching. They considered Social networking and Web designing least important.

Many questions of the interview were related with this research question. There were a whole range of answers on various themes by the eight teachers. Notably, there was no negative perception or attitude towards use of ICT in science teaching. Responses obtained from the teachers had a common positive theme in terms of attitude and perceptions towards ICT. They thought that ICT will enhance their lessons leading to more student engagement, a shift from traditional method of teaching to student focused learning. In addition, students would become creative and responsible users of ICT. The teachers also believed that ICT will provide overall satisfaction to teaching profession as more learning goals can be achieved using ICT. They considered ICT as a source of readily available resources that they can utilise in their daily teaching learning processes. However, some teachers thought that too frequent use of ICT may be counterproductive.

The importance of teachers' beliefs and attitudes was highlighted by Siorenta and Jimoyiannis (2008) in a Singapore study. Acceptance of ICT as a useful tool for teaching was assessed by using Technology Acceptance Model (TAM) through perceived ease of use, technological complexity and facilitating conditions. In this study, ease of use or user-friendly nature of ICT was reported even by teachers who were not well trained on the technology. The fact that a variety of types of ICT tools were used by Bhutanese teachers demonstrates that technological complexity is not a serious issue. Many teachers reported lack of computers, labs, projectors, internet connections and other resources in the school. So, facilitating conditions are not up to the mark in Bhutanese schools. A positive attitude of some teachers was reported by Pierce and Ball (2009) in Australia. Although in this work, mobile technology was not particularly studied, one teacher did mention about students using mobile phones with internet to access information at any time anywhere. Such an advantage was reported by students and teachers in a Cyprus study (Ozdamli & Uzunboylu, 2015).

Clearly, excepting for some factors, teachers generally have positive perceptions and attitudes about use of ICT in science teaching. The second question in this respect has been answered by the findings of this study in the Bhutanese context.

6.4 Research Question 3

What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms?

The question has three aspects: types of ICT, how they are used and frequency of use. All these are answered by teachers in responses to various survey and interview questions and TPACK assessments.

Answers to survey questions revealed that most teachers owned a computer with or without internet access. In daily life, they used Mobile phones, Internet, Social networking, Word processing and Email communication more frequently than others. On the other hand, they were interested to Mobile phones, Internet, Social networking, Word processing, Email communication, Printer Spreadsheet, Slideshow, Data projector and Digital camera excepting, Databases, E-journals and Web designing, for which, probably, they were not proficient. This is evidenced to some extent by their high level of confidence in using only seven of the ICT items. Although teachers felt the same seven items more important for science teaching, more frequent use was only of Mobile phones with internet access, Internet browsing and to some extent, Word processing. The difference between the two might be due to the problems of facilities at schools. Evidently, mere ownership of a computer may not mean that it is used in teaching. The chances of using ICT increases as the teacher possesses a computer and has Internet access. This was what was revealed in the studies by Wilson-Strydom, Thomson, and Hodgkinson-Williams (2005). It is also a fact that many teachers use ICT only for their own use like preparing lessons and assignments, as was expressed by some teachers in the interviews.

In the interview responses, teachers generally used websites, Google apps, PowerPoint, Spreadsheets, worksheets, videos, projectors, animated movies. These software applications were used for interactive teaching, disseminate ideas, collaborative learning and communication among students, enquiry-based learning, project-based learning, student-centred learning, teamwork among students, sharing video lessons and power points, as resources other than textbooks, to relate basic knowledge with practical life. simulation, concept mapping, modelling, action research by students, global level participation by students. Thus, many types of ICT tools and software were used for teaching, helping students to learn topics outside the textbooks and evaluation of their learning progress. Some of these benefits were also found in the studies of (BECTA, 2003; Dawson, 2008; Osborne & Hennessy, 2003). It was especially noted by Osborne and Hennessy (2003) that the use of different ICT tools improved learning of both theoretical and practical aspects. Other researchers like Su (2008),

Luu and Freeman (2010) and Ross et al. (2010) also support these observations. Therefore, the high level of benefits of ICT in science teaching has been generally agreed upon.

One teacher reported that students use smart mobiles with internet very frequently. In the interviews, teachers also told about various software applications they used for academic and administrative purposes created and used by all teachers. Many teachers used ICT to plan lessons, continuous assessment and making notes and for evidence-based records, concept mapping and determination of lecture method, assessment of students' project works.

Teachers perceived that such use of ICT in teaching adds variety to teaching strategies, cater to technological needs of students and introduce them to digital world. They believed skills learned at school will directly impact their ICT use in society. Use of ICT by students promotes critical thinking among them.

Teachers sometimes shared clips on lesson topics shared with other teachers. Many times, they received help from IT officer for solving technical problems associated with use of some software. Some teachers allowed students also to use projectors for presentations and even involved them in deciding the topics for which ICT tools can be used. Generally, teachers used ICT once a week to once a month, depending on the need and facilities available.

These patterns of ICT use reflect the global trends reported by Law and Yuen (2006), for which, the school factors were important. The facilities and resources available at the school and the top management support are crucial factors. This single factor might have led to the less than 60% teachers using ICT in teaching found in this study also. Examples of ICT being used either as supplementary to current traditional methods or as a new way of teaching were provided by the interview responses of teachers in this study. This finding is substantiated by similar observations by de Koster, Kuiper, and Volman (2012) and by Smeets and Ton (2001) in the Netherlands. The limitations of skills that teachers develop from fresh to experienced professionals with ICT training is reflected in their initial limited use of tools like word processing, Google search, Email and PowerPoint only to more sophisticated use of Web designing, discussion groups, E-journals and Databases. This trend noted in this study supported the previous findings (Dawson, 2008). The actual classroom strategies may vary from simple Power Point explanations to showing animated videos to students and further to involving students in making presentations etc. in the class as was noted in this study. Thus, the six global types of teaching (*Technical-demo, Explain-the-screen, Link-screen-board,*

Discuss-the-screen, Spot-and-show, and *Sherpa-at-work)* proposed by Drijvers et al. (2010) can also be traced in the case of this study.

Possible solutions to shortage of computers and labs may be time allocation for students to use ICT. One teacher observed that there is mismatch of curriculum with ICT use, which needs to be reviewed. To update teachers' ICT knowledge especially on application side, school-based training programmes for teachers, external training programmes and refresher courses were suggested.

TPACK scores show the effectiveness of integration of technology into the pedagogies, as Kohler (2000) pointed out. Most teachers ranged from average to high level of TPACK scores in this study indicating at least minimum required integration of ICT into their teaching. Also, the Pearson's test (Table 4.17) for TPACK and ICT variables (daily use, interest, confidence, use in science teaching and importance) showed a linear positive relationship. The results indicated that higher TPACK score was directly linked to more usage of ICT, greater interest, increased confidence level and consideration of ICT as useful in teaching. The different levels of (average to high levels) integration of ICT into teaching was also reported previously (Donnelly, McGarr, & O'Reilly, 2011)., based on which they categorised teachers into various types of adopters. However, they did not use TPACK scores in their study. All these types from traditional teacher to innovative adopter can be traced in this study too.

All four elements of ICT (ICT as an object, as assisting tool, as a medium for teaching and learning and as a tool for organisation and management in schools (Cavas, Cavas, Karaoglan, & Tarik, 2009) are visible in these findings. ICT has been used as an object by itself when various tools were used for different purposes. The four elements as described in the Review of Literature chapter can be located among the above findings. Teachers used various types of ICT as instruments for data constructs. The pattern is expressed as many teachers report similar types of ICT uses. Dawes (2001) pointed out that such patterns of use ultimately lead to ICT becoming an assisting tool for teaching. Various uses of ICT in teaching listed by teachers show how this becomes assisting tool. ICT becomes an assisting tool for both teaching and learning. The increased effectiveness reported by teachers is due to ICT being transformed from an object by itself to an assisting tool, as Dawes points out. The progress from assisting tool to medium of teaching occurs when higher than average level of TPACK helps teachers to integrate ICT successfully into teaching, as they report teaching becoming more student-centred and interactive with cooperation (Beauchamp & Kennewell, 2008). Cooperative

learning by students was reported by more than one teacher and it has been shown to be beneficial (Schulz-Zander, Büchter, & Dalmer, 2002). Thus, empowerment of students (Selwyn, 2007) to decide what they want to learn using ICT becomes important. Unfortunately, most teachers reported that the students were not involved in these types of decisions. On the other hand, guidance for weaning them away from improper use of ICT was stressed. Although teachers said they used ICT to prepare lessons and other teaching materials and adapt their teaching strategies (Bhagat, Chandak, & Deosthale, 2017), they were not done to sufficient extent. Use of ICT for organisation and management of the school when some teachers said that they were ICT teachers and helped the school management in designing websites and software applications for student evaluations and formulating strategies of ICT use in the school curricula, sharing knowledge and information with other teachers and in-school training of other teachers in ICT. Solar, Sabattin, and Parada (2013) and Hoque, Razak, and Zohora (2012) have listed many of the uses in this respect.

The above discussions clearly lead to answer the third research question.

6.5 Research Question 4

What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

From survey findings, lack of resources, and lack of time were the main problems for teachers in integrating ICT into their teaching, as they had lack of skills and interest in using Databases, E-journals and Web designing and hence used them less frequently in their daily life or in teaching.

The interview responses revealed a variety of factors inhibiting ICT use in teaching. Shortage of computers and other resources, non-availability of stable internet connections and lack of skills among teachers and students. Teachers also expressed lack of time to prepare ICT materials as factors affecting use of ICT in schools. According to some teachers, students had less opportunity to work independently and limited role in decision making about ICT use. One teacher raised his concerns that too much dependence on ICT may hinder student's writing and spelling skills and may impact one's culture and traditions of the country.

Some other problems highlighted by the teachers in connection with their use of ICT in classes were the need to monitor and guide students from going wrong ways, requirement of training, workshops and refresher courses for teachers to update their ICT knowledge.

Some limiting and promoting factors were discussed by Badia, Meneses, and Sigalés (2013). In their study, the teachers listed utility in the given educational context, teacher support for its use by students, availability and access of ICT in classroom, technological expertise of teacher and access to ICT outside classrooms, as the factors. Many of these factors were mentioned by teachers in this study also. The findings of Pelgrum (2001) also largely support the identified factors of inhibition or promotion in this study. The Australian study by Bingimlas (2009), the Saudi study by Al-Alwani (2005) and the East African study by Tedla, (2012) draw our attention to lack of skills, confidence and interest as some possible factors inhibiting use of ICT in schools by teachers. The survey findings in this study also showed teachers were interested in using Mobile phones, Internet, Social networking, Word processing, Email Communication, Printer, Spreadsheet, Slideshow, Data Projector and Digital Camera out of 13 items of ICT but used only, Social networking, Word processing and Email Communication for daily use and just Mobile phones and Internet for science teaching even if the same seven were considered important for science teaching. There was lack of confidence in using most of the 13 applications listed, which could be due to lack of competence, as competence arises out of skills learned and confidence comes from competence. Bingimlas (2009) provided similar reasoning. As was explained by Papaioannou and Charalambous (2011) and by Afshari, Bakar, Luan, Samah, and Fooi (2009) absence or presence of positive factor or negative factor in different degrees can promote or inhibit use of ICT by teachers. This effect is not explicitly available in this study. Some of the interview responses on how use of ICT in teaching is helped by some factors (Research Question 3) can be considered as promoting factors. Many other researchers had also obtained similar results.

The factors identified as promoting or inhibiting in this study were largely supported by many other research results. Therefore, the research question 4 has been answered satisfactorily.

6.6 Summary of Findings

The main aim of this study was to understand the pattern of ICT use in middle secondary science education in the Himalayan Kingdom of Bhutan. This study was an attempt to explore the perceptions and attitudes towards ICT by science teachers; to understand the skills and confidence level of science teachers to use ICT, to determine the types of ICT commonly used by science teachers and to learn about factors that affected the use of ICT for effective implementation of ICT in science education. The study also explored the level of TPACK amongst the science teachers in Bhutan.

Briefly, all the research questions have been answered satisfactorily and the findings of this study are supported by many other research reports. The answers to the research questions from this study are summarised below.

Research Question 1. What is the level of ICT knowledge and skills of middle secondary science teachers in Bhutan?

Many of the Bhutanese middle secondary science teachers had reasonable levels of ICT knowledge and skills. Although most of them were interested, using in daily life and recognised the importance of many items of ICT in science education, they were less confident in using most of these applications. The need to elevate their knowledge and skills to high levels for increased confidence and use of ICT is brought out by this finding. In-school training, external training, refresher courses and other development programmes were suggested by teachers themselves to solve this problem.

Research Question 2. What are the perceptions and attitudes towards ICT use amongst middle secondary science teachers in Bhutan?

The positive perceptions and attitudes towards use of ICT were reflected in actual use of many tools in many ways by different teachers in practice. However, their limited skills and confidence in using only certain ICT tools stood in the way of realising the full potential of ICT in science education.

Research Question 3. What are the various types of ICT used by middle secondary science teachers and how, and to what extent are they being used, specifically in classrooms?

The Bhutanese middle secondary science teachers used many ICT tools right from preparation of lessons to teaching in the class, giving internet-based assignments and assessing the performance of students. However, teachers who had more knowledge of ICT showed greater variety and innovativeness in using ICT than those who did not possess this knowledge. Some teachers with good knowledge of ICT even helped the school management in designing websites, academic and administrative applications. Most of them interacted with other teachers for information sharing and teaching skills. However, limitations of resources and facilities at the school stood in the way of full-scale application of ICT more frequently.

Research Question 4. What are the factors that promote or inhibit the effective implementation of ICT in Bhutanese middle secondary science classrooms?

Generally, presence or absence of certain factors in various degrees determined whether they promoted or inhibited ICT use in schools. More specifically, teachers reported lack of skills, lack of time and lack of resources as the main barriers to more extensive adoption of ICT in their schools.

All these findings were generally supported by many other research works reported in the literature.

6.7 Limitations of Study

Some of the limitations associated with the current study were identified by respondents during the survey. Although the original intention was to collect survey data from all the middle secondary teachers (189) only 162 responded, giving about 85.7% response rate. However, the sample size was smaller than the optimum required. Only three groups of students participated in focus group discussion due to consent factor of the concerned teachers and due to difficulties faced to conduct interviews as some of the schools were in far flung places in Bhutan.

The other limitation was the method of sending the questionnaires to the respondents. The questionnaires were sent using the postal services in Bhutan, which often was not reliable. Therefore, there was increased probability of missing posts and the survey instruments not reaching the intended respondents. Furthermore, respondents might have misinterpreted some of the questions, as the researcher was unable to assist due to geographical distances. These limitations impose limited generalisability of this research findings.

Minor drawbacks were encountered while conducting interviews using online applications (Messenger app). Issues such as clarity of recordings due to poor network connectivity were identified. This could have been prevented, had the interviews been conducted face to face. But this was beyond the control of researcher, as it was the preference of the participants.

6.8 Recommendations

The findings from this study was significant and timely; particularly as Bhutan is emerging into the global digital world. The findings could be used by the Ministry of Education to further promote and enhance ICT in its education system. The relevant stakeholders can utilise the findings while formulating ICT policies and implementing ICT in education, and teacher development programs. The following specific recommendations arising from this research, are given for attention of the appropriate authorities.

1. It is recommended that the Ministry of Education provide necessary ICT resources for teachers in schools. This may involve constructing more computer labs, providing more computers and internet access, back up of a well-qualified IT professional to solve technical problems whenever they arise.

2. It may be a good idea to recruit one well-trained IT teacher in every school to facilitate full integration of ICT for academic and administrative purposes. The IT teacher may be used as an internal trainer for teachers of the schools who lack ICT skills.

3. In addition, science teachers must be trained to use ICT effectively using appropriate in-school training, external training, refresher courses and other suitable development programmes. The government may think of establishing a nodal agency for arranging and coordinating these programmes nation-wide.

4. In teacher training colleges, there should be special attention on ICT training of pre-service teachers. They need to be trained to an adequate level to be interested and confident to use a wide variety of ICT tools in teaching when they go for teaching jobs.

5. On the part of teachers, they should involve students in determining the choice of ICT tools for each topic. They should use social networking platforms to create groups of students facilitating the study of the subject. A course page in such sites may also be useful. All the information regarding the course, learning materials, examination dates, results, assignments etc can be given on this page, Students are to be provided facilities to ask questions and clear their doubts through mutual interactions and interactions with the teacher.

Ongoing professional development programs for teachers should cater to those ICT areas where teachers are less competent. TPACK could be used as a guide to formulate professional developments programs for science teachers. Additionally, teacher's workload might need evaluation so that enough time is available for teachers to plan and use ICT in their teaching. This may imply appointment of more science teachers in each school.

6.9 Implications for Further Studies (Research)

The following may be some areas of future research.

1. The current study had a very limited scope. More extensive studies using more teachers as participants can be considered. Such studies will yield deeper understanding of ICT usage amongst teachers in Bhutan.

2. Only the teacher angle was focused. There should be studies focusing on students. This will provide students' perspectives on ICT usage in Bhutan.

3. The link between availability of facilities and extent of ICT use was indicated in this study. More detailed investigation needs to be done.

4. This study was done on middle secondary schools. Such studies on higher secondary schools and college/university contexts need to be done. The availability of resources may differ in different institutions. Considering such elements will provide clearer picture of ICT usage across range of educational settings in Bhutan.

5. Studies on comparison of teacher and student perspectives may be useful.

6. The study did not link student performance with or without ICT. This comparative assessment is highly required. Such investigation will reveal the impact of ICT on students' achievements and will help implement guided ICT policies and curricula.

7. The impact of educational and ICT policies of the government and allocation of funds on the progress of ICT integration in teaching at national level is a matter of great interest and can be used to guide future policies aligning with the philosophy of Gross National Happiness.

6.10 Conclusion

The aim of this study was to explore pattern of ICT use in middle secondary science education in the Himalayan Kingdom of Bhutan. This study was an attempt to explain the types of ICT used by middle secondary science teachers, their perceptions and attitudes; skills and competency to use ICT in science teaching including their TPACK and factors related to ICT usage. All the research questions framed for achieving the research aim were answered satisfactorily supported by works done by others. It can be stated with certain confidence that the intended aim of this research has been achieved.

This current study was a first of a kind that investigated specifically the trends of ICT use in Bhutanese middle secondary schools with a wider range of teacher population. Overall, the findings showed middle secondary science teachers to be confident in using basic ICT, exhibited positive attitudes towards use of ICT and demonstrated competent in TPACK.

A lack of time, inadequate skills and unavailability of resources were the main factors that prevented use of ICT in middle secondary science education.

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APPENDICES

Appendix A: Informed Consent Form (Teachers)

Semi-structured Interview (TEACHERS)

Information Sheet

Research Title: The Use of ICT by Science Teachers in Middle Secondary Science Education in the Himalayan Kingdom of Bhutan

Dear Sir/Madam,

A warm greeting to you!

My name is Sampa Tshewang. I am currently undertaking my PhD study in Edith Cowan University, Perth, Western Australia.

May I kindly seek your participation in my study exploring the use of ICT use by science teachers in middle secondary science education in Bhutan? The study aims to explore, and understand, the ICT knowledge and skills; attitudes and perceptions towards ICT; and in an overall sense the TPACK knowledge of Bhutanese science teachers. It also seeks to determine the factors that may affect the appropriate implementation of ICT in science education in Bhutan.

All your responses will remain strictly confidential, ONLY the researcher and his supervisors will have access to your responses. The information will not be used to identify individuals or groups, other than for the purpose of addressing the focus of this study. You will not be identified in any of the reports or publications associated with the study. This study has been approved by the Human Research Ethics Committee from the University of Edith Cowan and has permission from the Ministry of Education, Royal Government of Bhutan.

Your participation is purely voluntary, and you may withdraw from the study at any time.

It is expected that this interview will take approximately 45-60 minutes.

Please contact me if you have any questions regarding this study. If you wish to speak with an independent person about the conduct of the study, please contact Ms Kim Gifkins the Research Ethics Officer for the University on +61 8 6304 2170.

Thank you for your valuable time!

Yours Sincerely,

(Sampa Tshewang)
PhD student
Edith Cowan University
2 Bradford St
Mount Lawley 6050 WA
Australia
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Informed Consent Form (TEACHERS)

Research Title: The Use of ICT by Science Teachers in Middle Secondary Science Education in the Himalayan Kingdom of Bhutan

Researcher: Sampa Tshewang (PhD student)

I……. have read the included information sheet and been informed about all aspects of this study. I am happy to participate in the study and being involved in interviews. I agree for the interviews to be digitally audio recorded on the understanding that this is for verification purposes and will not be used for any other purposes. I understand participation is voluntary and that I may withdraw from the study at any time. I understand that the study has been approved by the ECU Human Research Ethics Committee and has the official permission from the Ministry of Education.

I agree that the research data gathered for this study may be published provided I am not identifiable in any of the reports that are produced.

Signed…… ……Date…….

School……

Appendix B: Informed Consent Form (Students)

Focus Group Discussion (STUDENTS)

Information Sheet

Research Title: The Use of ICT by Science Teachers in Middle Secondary Science Education in the Himalayan Kingdom of Bhutan

Dear Student,

A warm greeting to you!

My name is Sampa Tshewang. I am currently undertaking my PhD study in Edith Cowan University, Perth, Western Australia.

May I kindly seek your participation in my study exploring the use of ICT use by science teachers in middle secondary science education in Bhutan? The study aims to explore, and understand, the ICT knowledge and skills; attitudes and perceptions towards ICT; and in an overall sense the TPACK knowledge of Bhutanese science teachers. It also seeks to determine the factors that may affect the appropriate implementation of ICT in science education in Bhutan.

All your responses will remain strictly confidential, ONLY the researcher and his supervisors will have access to your responses. The information will not be used to identify individuals or groups, other than for the purpose of addressing the focus of this study. You will not be identified in any of the reports or publications associated with the study. This study has been approved by the Human Research Ethics Committee from the University of Edith Cowan and has permission from the Ministry of Education, Royal Government of Bhutan.

Your participation is purely voluntary, and you may withdraw from the study at any time.

It is expected that this interview will take approximately 45-60 minutes.

Please contact me if you have any questions regarding this study. If you wish to speak with an independent person about the conduct of the study, please contact Ms Kim Gifkins the Research Ethics Officer for the University on +61 8 6304 2170.

Thank you for your valuable time!

Yours Sincerely,

(Sampa Tshewang)
PhD student
Edith Cowan University
2 Bradford St
Mount Lawley 6050 WA
Australia
Mobile: Provided (Australia)
Provided (Bhutan)
Email: [redacted]
stshewan@our.ecu.edu.au

Informed Consent Form (STUDENTS)

Research Title: The Use of ICT by Science Teachers in Middle Secondary Science Education in the Himalayan Kingdom of Bhutan

Researcher: Sampa Tshewang (PhD student)

I……. have read the included information sheet and been informed about all aspects of this study. I am happy to participate in the study and being involved in interviews. I agree for the interviews to be digitally audio recorded on the understanding that this is for verification purposes and will not be used for any other purposes. I understand participation is voluntary and that I may withdraw from the study at any time. I understand that the study has been approved by the ECU Human Research Ethics Committee and has the official permission from the Ministry of Education.

I agree that the research data gathered for this study may be published provided I am not identifiable in any of the reports that are produced.

Signed……...Date…….

School……

Appendix C: Questionnaires

Questionnaires

Questionnaire items and interview questions adapted from Vaille Dawson (2008) and Hanaa Eid M AL Harbi (2014).

Research Topic: Use of ICT by Science Teachers in Middle Secondary Science Education in the Himalayan Kingdom of Bhutan.

About ICT in Brief

Information and Communication Technology (ICT) is a term that includes any communication device or application that can be used in the teaching learning process. It includes hardware such as computers, interactive whiteboards, digital cameras, projectors, scanners; software such as word processor programs and communication networks such as Internet and email.

How to Complete the Questionnaire:

Please "tick one" or "tick all that apply" for each question. If you have any other comments write wherever it is applicable. Your response will remain fully confidential

Part A: Demographic Information

1. Please tick the most appropriate one

   Your age (years): □ Under 25 □ 25-29 □ 30-39 □ 40-49 □ 50 and above

   Gender: □ Male □ Female

   Teaching experience (years): □ Less than 5 □ 6-10 □ 11 and above

   Your qualification: □ PTC □ B.Ed □ PGCE/PGDE □ Master □ PhD

   Science subject that you are teaching: □ Biology □ Chemistry □ Physics

   Service type: □ Regular □ Expatriate □ Temporary/Contract

   I own: □ a computer with internet access

   □ a computer without internet access

   □ I do not own a computer

Part B: Use of ICT in daily life (Personal)

1. How often do you use the following ICT? (Please tick the most appropriate one)

ICT Tools	**Never**	**Rarely** (once in a month)	**Frequently** (once in a week)	**Always**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g., Face book)				
Word processing (e.g., MS Word)				
Slideshow (PowerPoint)				
Spread sheet (e.g., Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

2. Please indicate your interest to use the following ICT (Please tick the most appropriate one)

ICT Tools	**Not interested**	**Somewhat interested**	**Interested**	**Very interested**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g., Facebook)				
Word processing (e.g., MS Word)				
Slideshow (e.g., PowerPoint)				
Spread sheet (e.g., Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

3. Please indicate your confidence level to use the following ICT (Please tick the most appropriate one)

ICT Tools	**Not confident**	**Somewhat confident**	**Confident**	**Very confident**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g. Facebook)				
Word processing (e.g. MS Word)				
Slideshow (e.g. PowerPoint)				
Spread sheet (e.g. Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

Part C: Use of ICT in Science Teaching

1. How often do you use the following ICT to teach science? (Please tick the most appropriate one)

ICT Tools	**Never**	**Once in a month**	**Once in a week**	**Daily**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g. Facebook)				
Word processing (e.g. MS Word)				
Slideshow (e.g. PowerPoint)				
Spread sheet (e.g. Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

2. How important are the following ICT in science education? (Please tick the most appropriate one)

ICT Tools	**Not important**	**Moderately important**	**Important**	**Very important**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g. Facebook)				
Word processing (e.g. MS Word)				
Slideshow (e.g. PowerPoint)				
Spread sheet (e.g. Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

Part D: ICT Resources

1. Which factor(s) prevents you from using the following ICT? (Please tick the most appropriate one)

ICT Tools	**Lack of skills**	**Lack of interest**	**Lack of resources**	**Lack of time**
Internet Browsing				
Email Communication				
Data Projector				
Digital Camera				
Printer				
Social networking (e.g. Facebook)				
Word processing (e.g. MS Word)				
Slideshow (e.g. PowerPoint)				
Spread sheet (e.g. Excel)				
Databases				
Mobile phones with internet access				
E-journals				
Web designing				
Others (specify)				

Part E: TPACK (Technological Pedagogical and Content Knowledge) adapted from *Hanaa Eid M AL Harbi (2014).*

1. Please indicate your level of competence against each statement. (Tick the most appropriate one)

Statements	**No Competence**	**Little Competence**	**Not Sure**	**Moderate Competence**	**Much Competence**
I can update an instructional material (paper based, electronic or multimedia materials, etc.) based on the needs (students, environment, duration, etc.) by using technology.					
I can use technology to determine students' needs related to a content area in the pre-teaching process					
I can use technology to develop activities based on student needs to enrich the teaching and learning process.					
I can plan the teaching and learning process according to available technological resources.					
I can develop appropriate assessment tools by using technology.					
I can implement effective classroom management in the teaching and learning process in which technology is used					

I can assess whether students have the appropriate content knowledge by using technology.					
I can apply instructional approaches and methods appropriate to individual differences with the help of technology.					
I can use technology for implementing educational activities such as homework, projects, etc.					
I can use technology-based communication tools (blog, forum, chat, e-mail, etc.) in the teaching process.					
I can be an appropriate model for the students in following codes of ethics for the use of technology in my teaching.					
I can use innovative technologies (Facebook, blogs, twitter, podcasting, etc.) to support the teaching and learning process.					
I can use technology to update my knowledge and skills in the area that I will teach.					
I can update my technological					

knowledge for the teaching process.					
I can use technology in every phase of the teaching and learning process by considering the copyright issues (e.g. license)					
I can follow the teaching profession's codes of ethics in online educational environments (WebCT, Moodle, etc.).					
I can provide guidance to students by leading them to valid and reliable digital sources.					
I can behave ethically regarding the appropriate use of technology in educational environments.					
I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process					
I can use technology to find solutions to problems (structuring, updating and relating the content to real life, etc.).					
I can become a leader in spreading the use of technological					

innovations in my future teaching community.					
I can cooperate with other disciplines regarding the use of technology to solve problems encountered in the process of presenting content.					

Appendix D: Semi-structured Interview Questions

adapted from *Hanaa Eid M AL Harbi (2014)*

1. What are the main purposes you want to use ICT for with your students?
2. What are you focusing on now in the use of ICT?
3. What is the value in having your students use a computer?
4. How does ICT fit into your teaching overall?
5. How do you contribute to school ICT planning? What would you like to contribute?
6. What involvement do you have with learning communities that use ICT?
7. Is there any pattern to your ICT usage? How often do your students use ICT? Do they work independently or in groups?
8. What teaching strategies have you used, and do you use consistently where ICT is involved? How do you decide on the strategy you use?
9. What activities have you used computers for in the last term?
10. To what tasks have you applied computers during the last term? How have you determined those tasks?
11. Have you assessed work that students have done with ICT? How has this been included with your overall assessment processes?
12. In what ways do you connect what the students do with ICT and the way ICT is used in our society?
13. What potential do you see for ICT to support learning and teaching processes with your class?
14. What do you see as your main roles when using ICT with your classes? What roles do the students have?
15. In what ways are students permitted to contribute to decisions about the use of ICT?
16. What skills do you have in using ICT and what steps do you take to develop the skills you need?
17. How do you feel when you use a computer and when you support your students in using computers?
18. What concerns do you currently have for the way in which ICT is used to support learning and teaching in science?

Appendix E: Focus Group Questions (Students)

1. How often do you use ICT in your class? **(Use of ICT in classrooms)**
2. Give some examples of activities carried out using ICT/computers?
3. Do you have opportunities to interact with ICT in your science classroom? **(Opportunities to interact with ICT)**
4. Give some examples of ICT that you are confident to use in your learning? **(Examples and confidence level of students)**
5. According to you what is the ICT status of your school? **(Availability of ICT resources in schools)**