FACTORS AFFECTING ENGAGEMENT WITH INFORMAL SCIENCE LEARNING IN THAILAND: A REGIONAL ANALYSIS

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Abstract

There is currently minimal understanding as to how informal science learning affects young people's scientific performance, attitudes and experiences at a regional level in Thailand. This thesis is the first to investigate this topic by examining the factors affecting engagement in science learning in regional informal settings. It focuses on 'underserved' students from remote schools with poor access to science learning in informal settings and educational support.

This research aims to examine the impact of the activities offered by the Science Caravan, a travelling informal science learning activity, on young people in four regions of Thailand and to explore their informal science learning experiences, through five research questions; (1) What settings or resources are available to young people for informal science learning at the regional level?; (2) What are the main factors affecting the experiences of Thai young people in informal science learning?; (3) How do informal science learning activities meet the needs of different demographic groups?; (4) What learning and other outcomes do young people obtain from participating in regional informal science activities?; and (5) How can this learning be applied to other informal science communication projects at the regional level?

The research draws on a number of key theoretical models, including cognitive and social constructivism, which is used to examine how participants obtained and constructed their knowledge via engagement with informal science activities (Berkeley Graduate Division, 2017; Van Der Veer, 2007). The VARK model is also used to examine individual learning behaviour (Ainsworth and Eaton, 2010), and the Visitor Engagement Framework (VEF) provides an opportunity to examine learning via social interaction in informal learning environments (Barriault and Pearson, 2010). Falk and Dierking's (2000) contextual learning model is utilised to investigate personal, physical and social factors affecting the informal science learning experiences of young people. Finally, the Generic Learning Outcomes (GLOs) are used to examine the outcomes of learning achieved from engagement with informal science activities comprised within the Science Caravan (Art Council England, 2017).

Mixed methods were used in this research, which employed triangulation to achieve convergence of results from two different methods (Greene, Caracelli, and Graham, 1989; Bryman, 2006 cited by Creswell and Plano Clark, 2011). Pre and post engagement questionnaires were designed to collect quantitative data from 1,400 participants across four different regions (350 participants for each region). Semi-structured interviews were employed for in-depth exploration of the experiences of 40 young people (10 participants for each region), 20 teachers (five teachers for each regions) and 22 National Science Museum, Thailand staff (two directors and 20 science communicators). The Wilcoxon signed-rank test was used to identify the changes in attitudes towards science and scientific knowledge from pre- and post-caravan responses taken from the same individual. The Kruskal-Wallis test was used to investigate independent data comprising more than two independent groups, and the Mann-Whitney U test when two independent variables were being explored (Field, 2009). For qualitative data analysis, inductive thematic analysis (TA) was used to capture any themes within the interview results (Braun and Clarke, 2013).

This research identifies a number of key settings and resources which are available to young people regionally, including the public library, the school library, internet resources, as well as local national parks, zoos, science museums and discovery centres. The location of the informal learning setting, its accessibility and usefulness are significant factors that influence in the uptake of informal learning by local young people. Beyond these resources, factors effecting young peoples' engagement with informal science learning include schools, teachers, family, friends, the government and other organisations (e.g. local university and local community institutes), with schools and teachers being the most significant factors in promoting informal science learning for young people based in different regions of Thailand.

The results suggest that young people learn from informal science activities both as individual learners and via social interaction. The results show that participants obtained and constructed their scientific knowledge and understanding by watching and observing activities, performing experiments, repeating activities and using experiences to solve science problems. In addition, sharing and discussion with other during participated in the Science Caravan.

Additionally, they also observed, discussed and shared information with others. Over 50% of participants has post-test knowledge scores which were higher than their pre-test scores, with participants in the Northeast showing the greatest improvement in terms of their post-test scores. There were minimal differences by region, age and gender in terms of which types of science activities were most popular with participants.

The results also present evidence of changing attitudes towards science and technology, amongst young people following engagement with the informal science activities, including a growing awareness of the relevance of science and technology to life, as well as the complexity of science and its role within society. In examining the learning outcomes from engaging, most participants showed high levels of agreement that the learning outcomes had been met, wanted to be involved in the activities and were following instructions. Over 80% of all of participants indicated attaining new scientific knowledge, promoting development of social skills, increasing self-confidence in presenting ideas in front of others, enjoying science activities, using knowledge from the science caravan to support learning in school, and sharing information to encourage science awareness to others after engagement with the Science Caravan. Older participants aged 13-15 and females were more likely to want to be involved in science activities, to read instructions, and to anticipate using their learning at school. Additionally, local teachers obtained new scientific knowledge and gained new ideas for teaching science.

Finally, three significant factors were identified in response to the five research questions; contexts of informal learning, knowledge construction and learning outcome. This research proposes a model based on these three contexts which can be used to investigate other contexts, other informal learning settings and different participants to expand knowledge and understanding in this area. This study of contextual learning, knowledge construction processes and outcomes from engagement with the Science Caravan can lead to further development of the Science Caravan, and this knowledge can also be applied to investigate other regional informal learning projects that may be occurring internationally.

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Abbreviations

GLOs	Generic Learning Outcomes
NSM	National Science Museum, Thailand
PUS	Public Understanding of Science
PISA	Programme for International Student Assessment
PEST	Public Engagement with Science and Technology
TIMSS	Trends in International Mathematics and Science Study
VEF	Visitor Engagement Framework
ZPD	Zone of Proximal Development

Chapter 1
Introduction

Overview

This chapter introduces this research on *Factors Affecting Engagement with Informal Science Learning in Thailand: A Regional Analysis*. The chapter explains the purpose of the research and motivations in examining the relevant factors which affect engagement in informal science learning among young people in Thailand. It also discusses the Thai context in terms of science literacy and education and identifies the relationship between informal science learning and the promotion of science education in the country. This chapter outlines the opportunities for, and needs of, young people in accessing informal science learning at the regional level. Additionally, it defines what is meant by underserved participants in the context of regional informal science learning in Thailand. Current solutions proposed by the Thai government and relevant organisations who are addressing the needs of underserved participants are also explored. The chapter also investigates existing informal science learning opportunities for underserved participants in Thailand, and highlights the gaps in research in this area. In addition, this chapter states the study's aims and research questions. It further outlines the research design used to explore the questions and introduces the ten chapters that compose this thesis.

1.1 Research background

In 2005, I started my career as a science communicator at the National Science Museum (NSM) of Thailand in the division of the Office of Public Awareness of Science. I was responsible for developing science activities for young children through the Child Development Project. For the following two years, I worked with the science team to support the development of science activities for rural children, including the Science Caravan (see section 1.2.7). Here I had the opportunity to help explain to young learners how they could gain science knowledge from hands-on exhibitions. My responsibilities also included assisting the central staff to ensure that science experiments ran smoothly. During this experience, I observed that many local students were willing to be involved with this project due to the benefits they would realise in terms of science knowledge and entertainment. Especially willing were rural children who came from remote schools located far from the setting of the Science Museum.

The caravan experience sparked my curiosity about how the Science Caravan affected rural children and developed their scientific knowledge and skills. I was also interested in finding out how they accessed and obtained science knowledge from other informal science learning resources which may or may not be available to them. I focused on rural children from remote schools because they have little access to opportunities for science learning in informal settings and poorer educational support. Children in rural areas were identified by the Thai government as needing support to improve their science learning (IPST, 2011), whereas young people from urban areas have more opportunities to access informal science learning events and have better support for science education in their schools (Lounkaew, 2013).

In order to promote science learning amongst children who lacked the opportunity to attend the original Science Caravan project, the NSM established the Science Caravan on a smaller scale in 2011 (see section 1.2.7). This caravan aimed to serve even more remotely located students who encountered obstacles in accessing the main caravan activity. These young people often also have little opportunity to access other science learning programmes due to their schools' limited budgets. The main participants in this new small-scale caravan were underserved young people in very remote areas.

My research aims to examine the impact of the activities offered by the small-scale Science Caravan on young people in the relevant regions and explore their informal science learning experiences. I hope that the knowledge gained from this examination encourages a better understanding of the impact of informal science learning on young people, including what science knowledge they obtain, how they obtain it outside of schools, and what obstacles they encounter in accessing science information. Furthermore, an investigation of the impact of participating in the Science Caravan on science learning can promote a better understanding of the ways in which rural children obtain scientific knowledge, how the science activities meet their needs, and how participation affects them in terms of learning and aspirations.

This can support the development of other regional informal science learning projects in countries facing similar infrastructure and demographic challenges.

The knowledge obtained from this research can also encourage the Science Caravan team to understand rural children's needs and to consider how this caravan project may support them. In addition, this knowledge can help the caravan team develop effective science activities to encourage the rural population to identify the importance of science. The knowledge generated in this research can be of interest to science educators, science communicators, science activity designers, and science museum or science centre staff, as it provides evidence on different learners in different settings. Furthermore, this research is the first examination of factors affecting rural Thai participants in informal science learning activities. Despite the Science Caravan having delivered activities for nearly 10 years, no studies examining the impact of these activities had been conducted.

1.2 Context of Thailand

1.2.1 Thailand

Thailand, sharing borders with Myanmar and Laos in the North, is in the Centre of the Indochina Peninsula. It is bordered to the South by the Gulf of Thailand and Malaysia and to the West by the Andaman Sea. Thailand's total area is approximately 513,000 square kilometres (198,000 square miles) (see Figure 1). Its capital and largest city is Bangkok. The total population of the country is around 65.32 million people (July 2016) (IPSR, 2016). The largest percentage of Thailand's population is 0 to 15 years old (17.18%), whereas the smallest percentage is 65 years old and above (10.21%). Most of the Thai population adheres to the country's official religion of Buddhism (93.6%). The remaining population is Muslim (4.9%), Christian (1.2%) and other (0.2%) (CIA, 2016). The majority of Thai people live in rural areas (51.59% of the total population), especially in the northeast (55.07% of the rural population) of the country. Whilst urban inhabitants make up 48.41% of the population (IPSR, 2016). According to the Rural Development Information Centre's 2014 report, most of the Thai population works in the agricultural sector (31.31%) and the general contract sector (25.96%). The rest of the population works in private companies (12.44%), the government sector (3.73%) and in aquaculture (0.41%). In terms of Thai education, 44.79% of the population have completed primary school only (9–12 years old), 15.78% have completed secondary school (13–15 years old), 13.58% completed high school (16–18 years old) and 8.84% completed higher degrees such as university and post-graduate degrees (Rural Development Information Centre, 2014).

Figure 1: Thailand and Southeast Asia

“Figure removed for copyright reasons”

Courtesy of the University of Texas Libraries, the University of Texas at Austin
Source: University of Texas Libraries (2015)

The National Statistical Office of Thailand breaks Thailand into four regions: the North, the Centre, the Northeast, and the South. The divisions are based on economic, social and ecological dimensions (United Nations Thailand, 2008).

(1) The North

Thailand’s North is mountainous and contains Thailand’s main forest. Many types of agriculture are present in this region, including wet rice farming, orchards and flower farms. The population in the North comprises around 18.75% of Thailand’s population (National Statistical Office, 2011).

(2) The Centre

The Centre of Thailand is the heartland and rice bowl of Asia, boasting the Choa Phraya River, which is the country’s main river for agriculture and transportation.

There are 26 provinces in the Centre. This is also the most populous region, at around 33.85% (Bangkok included) (National Statistical Office, 2011).

(3) The Northeast

The Northeast of Thailand or Isan, has poor soil and is mainly grassland, with sticky rice as its main crop. The Northeast population comprises approximately 33.77% of the Thai population, making it the second most populated region (National Statistical Office, 2011).

(4) The South

The South of Thailand experiences the highest levels of rainfall and is an important area of biodiversity. It has the lowest percentage of Thailand's population, at around 13.93% (National Statistical Office, 2011).

Each region has differing economic, agricultural and environmental priorities, and they also display unique social and religious expectations. For instance, in the Central region, the population tends to be highly competitive and relatively well off financially (True Plook-Pan-Ya, 2008). However, the Northeast population tends to emphasise humility and prefers a simple lifestyle. Southern inhabitants are predominantly Muslim and tend to strictly follow the teachings of Islam (Ghetchunoui, 2006). Conversely, inhabitants of the other three regions are predominantly Buddhist. Moreover, economic fundamentals such as employment are also different in each region. Most residents in the Northeast, for example, are farmers. In the South however, most plant rubber trees and produce raw rubber. In the North, most residents work in the agriculture sector. Recently, ecotourism has become important in the South and North because these regions boast many beautiful natural resources (United Nations Thailand, 2008). Thus, large economic differences remain amongst regions.

Thailand therefore differs from some western contexts in that it weighted to a younger rather than ageing population, has lower rates of school completion and differing economic considerations, but the existence of different contexts in the regions raises questions regarding how informal science learning affects learners across regions. It also raises questions about how young learners may utilise science in their future lives.

1.2.2 Thai culture

According to Thai culture, respect for hierarchy is very important. Children are taught to be respectful of their elders (Panit, 2014), as the Bun-khun custom emphasises indebtedness to parents, guardians, teachers and caretakers. Bun-khun is defined as the need to recognise the help of benefactors, and as a result of this cultural concept, it is typical for those in Thailand to be very willing to do good deeds to return favours. Carefully listening to the teachings of parents, teachers and elders is an important part of demonstrating respect to benefactors (Mulder, 1997). Additionally, Thai culture is closely associated with Buddhist teachings. Providing elderly parents with a good living, for example, is part of what Buddhists are taught they should do. Hence, many Thai families, especially rural families, are large families that include grandparents, parents and grandchildren who all live together and take care of each other. Elder family members tend to be respected by their children, with the youngest members typically caring for their grandparents. Therefore, teachings from elder family members are considered to provide significant support for younger members and are seen as key to ensuring proper behaviour, knowledge, and skills for the next generation (Nguyen, 2005).

Parents and teachers are considered vital to the learning of Thai young people. In Thai culture, parents are highly important throughout the lives of their children, from fostering the children’s growth to teaching basic living skills and guiding all actions until adulthood. Thai children are typically taught to respect and heed parents’ teachings. The belief is that if children listen to parents’ teachings, they will have a good future (Mulder, 2000). Teachers also play an important role in supporting Thai children’s learning, especially in rural communities. In Thai culture, teachers are representatives of moral goodness and knowledge. Thai students are taught to respect and behave appropriately towards their teachers (Deveney, 2005). Furthermore, in rural communities, local ‘wise men’ are also considered important. In rural areas, local wisdom can be defined as important knowledge that has been discovered through experience, trial and error, and has been tested over time within the local community. This accepted wisdom is considered profoundly valuable and is transferred to the next generation (Kanhadilok and Watts, 2013).

Thus, it is evident that hierarchy has a great impact on Thai culture. Families, teachers, and local wisdom all influence the learning of young people. This is particularly true in rural communities, as these areas have particularly strong links to Thai culture and local knowledge, which may contain long held superstitions.

1.2.3 Science in Thailand and attitudes towards science

Science has played an important role in Thai civilisation throughout history. In the Traiphum era, approximately 700 years ago, King Lithai of Sukhothai worked in the fields of geography, astronomy and cosmology, presenting many key findings on the cosmological system in the Theravada Buddhist book. In the Ayutthaya Kingdom of the seventeenth century, an interaction occurred between Siam and Europe. In this interaction, King Narai introduced astronomical equipment, and his curiosity drove him to perform several important experiments in cosmology (Hongladarom, 2004). King Rama IV, also called King Mongkut, realised the importance of science and technology for Western civilisation. During the 27 years he spent as a monk before ascending to the throne, he studied the sciences and technologies, including culture, language, and especially astronomy. In 1868, his prediction for a total eclipse proved accurate. Therefore, the 18th of August each year is named National Science Day to celebrate the anniversary of this total solar eclipse, and Rama IV is praised as ‘the Father of Thai Science’ (Ministry of Science and Technology, 2016). King Rama V, son of King Mongkut, carried on his father’s policy of transforming and developing Siam toward modernisation. The strength and potential of Rama IV and Rama V lay in realising the importance of science and technology and in attempting to transform Siam into a modern and progressive nation. Hence, Thailand was seen to be the safest place in which to live while Asia was being nationalised (Tinnaluck, 2005).

Achievement in science frequently represents the level of development of a nation and is seen to be a sign of strong progression. Countries which become world leaders succeed in science and technology (National Research Council, 2003). In Thailand, the government aims primarily to succeed as a developed country, to improve its quality of living and promote the potential of its citizens, through scientific knowledge to support sustainable development. Therefore, the Thai government has continued to promote development in the field of science (Schiller and Liefner, 2007). Developing employees who have scientific and technological skills is key to the success of a developed country (Becker and Maunsaiyat, 2002). However, due to a decreased number of students who graduate in science and technology, Thailand currently faces a shortage of qualified employees in these areas (OECD, 2013). In

2011, 9% of all employees in Thailand worked in the science and technology sector (3.3 million people). However, an increasing demand for science employees created a desire to aim for a goal of more than 50% of employees in science and technology fields (Ministry of Science and Technology, 2012). Thailand continues to face a shortage of science employees in meeting this expectation.

Moreover, in an age of international economic competition, manufacturing requires scientifically capable people with a good knowledge and understanding of science (Office of the National Education Commission, 2003). Advanced technologies are important in supporting quality production in industrial sectors. Importing these advanced technologies from developed countries, especially the US, is the Thai government's main strategy for promoting industrial development. Therefore, in economic terms, Thailand faces an imbalance whereby it imports high-cost technologies whilst exporting many low-cost agricultural products (Falvey, 2000). In addition, new research and innovations are scarce compared with countries located nearby, such as Singapore, Taiwan and Korea (Intarakamnerd et al., 2001). Despite these issues, in 2014, the Thai government succeeded in decreasing the imbalance of import-export technologies by promoting the production of technology products such as delivery trucks, cars and computer hardware (Observatory of Economic Complexity [OEA], 2014).

However, the lack of quality employees with knowledge in science and technology still remains, and the need to adequately resolve this problem is seen to be urgent (Ratanakul, 2012). The number of Thai university students who graduate in science and technology is decreasing rapidly because the subjects are perceived to be difficult (Suranaree University of Technology, 2015). The 2008 Thailand Science and Technology Indicator shows that the percentage of high school students studying science and technology was 60.01%, whereas the percentage studying social science and humanities was 39.99%. In higher education, however, there is a significant change, with only 29.89% of students studying science subjects (Ministry of Science and Technology, 2008). The difficulty of the science curriculum is a key obstacle, and many students decide to pursue other majors after they graduate from high school. Pruekpramool *et al.,* (2011) found that very few students rated science as their favourite subject amongst a variety of subjects, and in some cases, they rated it low as it seemed difficult and had a negative impact on their overall grade. A 2008 survey of Thai Public Opinion on Science and Technology illustrates that only 0.2% of 5,800 respondents, all new graduates from large cities, planned to take up scientific careers (National Statistic Office Thailand, 2008). However, Thai students and adults have a positive attitude towards science generally and recognise the significance of science and technology in their daily lives and their country's development (Yuenyong and Narjaikaew, 2009). According to the National Statistics Office of Thailand (2008), in a survey of public opinion on science and technology with 5,800 respondents, 93.45% of respondents perceived that 'science plays an important role in daily life', and 90.7% agreed that 'science and technology lead to a better quality of life'. In addition, 87.9% believed that 'science and technology are important to develop the country'. Thus, many in Thailand are aware of the significance of science and technology, but opt not to study science or embark on scientific careers.

In the current globally competitive economy, science and technology education is important for Thailand (Yuenyong and Narjaikaew, 2009). To improve the country's development, the Thai government searches for ways to motivate young people to become interested in science and continue to study science and technology to increase the number of employees in this sector (Quality Learning Foundation Thailand, 2015). Science education is therefore seen as an important way to promote the development of scientific literacy in the Thai population and to encourage young people to realise the importance of science to the country's development (Tasakorn and Pongtabodee, 2005).

1.2.4 Scientific literacy and education in Thailand

Scientific literacy is not confined to the context of science and its role in future careers. Having some level of scientific literacy can be helpful to everyone in making effective decisions and increasing opportunities for engaging in productive careers (Yuenyong and Narjaikaew, 2009). Osborne (2000) and Hodson (2003) recognise scientific literacy in four ways: cultural, utilitarian, democratic and economic. Cultural scientific literacy includes the development of a relevant capacity to understand science and technology from the media. Utilitarian literacy involves having science knowledge and skills, such as those of an engineer and technician, to support a scientific career. Democratic literacy increases science knowledge and understanding through vehicles such as making links between science, technology and society. Economic literacy includes formulating knowledge and skills to promote the growth of effective economic competition within the world market. While most students may not become professional scientists, they can benefit from being able to use scientific knowledge, scientific methods, and problem-solving habits in everyday life (Nuangchalearn, 2009). Though science education may only be one strategy for promoting scientific literacy, it plays an important role in providing a foundation. Hence, promoting the development of effective science education in schools is seen to be a helpful strategy for supporting the development of scientific literacy in general (Klahan and Yuenyong, 2008; Chalamwong and Pomlakthong, 2004).

In terms of science education in Thailand, there are three main systems: formal, non-formal and informal science education. In the formal science education context, scientific knowledge is provided in accordance with the national science curriculum. Assessment of learning outcomes within formal science education is usually clear, specific and compulsory. Non-formal education offers learning opportunities for people who did not obtain a basic education. This might include under privileged groups or adults who had to drop out of school but still want to continue their education. Science is usually part of the curriculum but might not be strongly emphasised as other knowledge and skills such as reading and mathematics is seen to be more critical for this group of learners. The Office of Non-Formal Education also offers a number of extra-curricular science activities for school children through a number of science centres. However, the content provided is often heavily linked to the national curriculum. Informal science education then includes any other forms of science education provided outside formal spaces, schools or classrooms (Office of Education Council, 2004).

Science has been part of the formal education in Thailand since King Rama V established basic science knowledge in the country. The first university was established in 1917 under King Rama VI, and science subjects were included in the university curriculum in order to provide medical students with scientific knowledge (Chularlongkorn University, 2016). Moreover, in 1960, the Ministry of Education set up a science curriculum in high schools; using basic and pure science the support the development of scientific knowledge among students (Wanichkul, 2012). The next reforms in science education, took place in 1990 and focused on scientific literacy, emphasising scientific knowledge, the nature of science and the relationship between science, technology and society (Sothayapetch *et al*., 2013).

In formal education, science is compulsory from the primary level to high school (7-18 years old) (Ministry of Education, 2008). In Thai schools, there are 480 science lesson units allocated to students in grades 1-6, with 80 units per year for each educational level. The duration of a unit is 50 minutes. Therefore, each year, students study science for 66.67 hours (Sothayapetch *et al*., 2013). This means that Thai students spend more hours studying science than all other students in Southeast Asia (Office of the Ministry Newline, Thailand, 2016). Nevertheless, Thailand ranked 54th among 70 countries in the Programme for International Student Assessment (PISA) in 2015. Thai students scored lower in scientific literacy than those from countries such as Singapore and Vietnam (IPST, 2015).

Moreover, Thai scores in science and mathematics, including critical thinking sections, were lower than international standards, and this is especially true for rural Thai students (Lounkaew, 2013). According to the Trends in International Mathematics and Science Study (TIMSS), in 2007, rural students from the South, North, Centre and Northeast had lower TIMSS results than students in Bangkok. Students in the Northeast had the lowest TIMSS results, along with the central region (excluding Bangkok). The average national scores were lower than the international standard which is 475. Students from Bangkok, the north and south regions attained levels at the intermediate international levels, with average scores between 475 and 550 (Dechasri and Benjawan, 2007; IPST, 2007).

The PISA 2015 and TIMSS 2007 results suggest failings in the Thai education system, particularly for those students based regionally. This was partly attributed to a shortage of funding in local schools (Tambunlertchai, 2015) as well as a lack of science teachers with scientific backgrounds, a particular problem in rural areas (Buaraphan and Sung-ong, 2009). Therefore, the Thai government has attempted to improve science education through funding to support effective science education in remote areas (Ministry of Science and Technology, 2016). Informal science learning is also considered a useful tool to support formal science learning in schools. The promotion of learning outside classrooms through informal learning venues and events aims to encourage Thai learners to develop their knowledge within flexible and comfortable learning environments (Muadhaisong, 2011).

1.2.5 Informal science learning in Thailand

Informal education or informal learning is defined by the Ministry of Education Thailand as lifelong learning that takes place outside of the classroom across a multitude of designed settings (Ministry of Education, 2007a). Thailand has had informal learning resources that support formal education since the first public library, called the 'Public Reading Room', was established in 1916 at Wat Suthat Thepwararam (Nimsomboon, 2003). Public libraries provide access to scientific knowledge and are available to all people. As such, they support the Thai government policy of increasing learning resources for local communities (Indrarakulchai, 2001). Nevertheless, a lack of funding to develop libraries and provide up-to-date resources, means that most libraries offer out-of-date materials (Nimsomboon, 2003).

Science museums are another example of a setting that supports informal science education for the Thai population. The first science museum was established in 1953 at Chulalongkorn University, by the Science Society of Thailand, in order to promote scientific knowledge and awareness (Promboon, 2007). Today, there are approximately 3,200 informal learning spaces where the public can access scientific information, including over 850 libraries at district and provincial levels, 293 museums, and over 1,200 parks (Ministry of Education, 2007b). These resources, however are primarily accessed by inhabitants of major cities. Furthermore, the cost of equipment, such as internet enabled computers, may also present barriers, particularly in rural areas (Srisawat, 2012). Although the Thai government provides many informal science learning resources, most people who access these resources come from the capital or main regional cities. Meanwhile, young people in remote areas still have few opportunities to participate in informal learning settings (Lathapipat, 2013). As a result, the Thai government is focusing on this group to develop its capabilities (National Science Museum Thailand, 2011).

1.2.6 Underserved participants in informal science learning

Thailand's education policy is to ensure that all young people have an opportunity to engage in formal education through primary schools (ages 7-12) and junior high schools (ages 13-15) (Office of Basic Education Commission Thailand, 2002). Even so, many learners lack sufficient opportunity to access education based on the standard curriculum. These students, especially those from impoverished backgrounds, are faced with multiple obstacles during their study. Moreover, rural families in poverty often send their children to small poor performing village schools (Keawmee and Sirisupaluk, 2007; Quality Learning Foundation Thailand, 2012b). These poor-performing schools have limited funding, few teachers and restricted resources. This group also encounters shortages in experimental equipment and tools that would support science education in their schools (Sinlarat, 2011), meaning that these students have fewer opportunities to develop their learning skills than students in schools in larger cities (Quality Learning Foundation Thailand, 2012a).

Hence, poverty can be a considerable obstacle for rural children, limiting their opportunities to access quality education and the achievement of rural students in science assessments tends to be lower than that of urban students, as reported in the PISA, TIMSS and the Ordinary National Education Test (Siamwalla *et al.*, 2011). In 2011, most educationally underserved students were children in the age range of 9-15 years old (99.69% of all underserved students; Office of Basic Education Commission, 2011; Quality Learning Foundation Thailand, 2012b; Thai Health Promotion Foundation, 2014). Educationally underserved students are defined as children who are from low income families, study in schools lacking educational tools, or have no opportunity for informal education. In 2015, there were 4.79 million students in rural areas, and approximately 60.23% of rural learners were defined as educationally underserved (2.89 million people) (Office of Basic Education Commission, 2015). According to Tumtong's (2014) report, in 2012, most Thai rural children, who were underserved learners, were in the Northeast, making up around 45.98% of all underserved learners. Meanwhile, poor rural underserved learners in the Centre accounted for approximately 17.14%, with 23.41% coming from the North and 13.15% from the South.

To meet these challenges, the Thai government has invested in the creation of opportunities for informal science education. For example, it plans to increase the number of informal learning settings and events in remote areas in order to decrease the inequality in science learning opportunities offered to young people throughout

Thailand and to promote science learning amongst rural children (National Science Museum Thailand, 2011).

1.2.7 The National Science Museum, Thailand (NSM) and the Science Caravan: Outreach programmes for local young people

The NSM is an important setting for informal science education in Thailand. The NSM was established in 1999 and opened to the public in 2000 to develop learning resources in science, technology, and biodiversity through the delivery of science activities, exhibitions, communication, and research and development. In addition, the NSM introduced an education programme for the improvement of knowledge, understanding, skills, attitude, conscience and imagination (National Science Museum Thailand, 2007). The NSM includes five museums: the Science Museum, Natural History Museum, Information Technology Museum, NSM Science Square, and the Rama 9 Museum (National Science Museum Thailand, 2004), as well as providing regional delivery services.

In 2005, the NSM developed a science outreach programme called the Science Caravan in order to support lifelong learning and formal education in science and technology at regional levels (Suroj, 2006). This was done to support the Thai government's policy of science learning for all (National Economic and Social Development Board, 2011). The goal of the caravan was to promote science learning outside the classroom with an aim of increasing the number of young people in Thailand's remote areas who are interested in science. The Science Caravan has over two hundred thousand participants per year, and it operates for two hundred working days a year. There are 15 staff members who are responsible for project delivery, which includes developing all associated science activities. This team of staff are supported by groups of volunteers (5-10), often university students, who support the programme's regional delivery. Despite its wide reach, there are still many children in Thailand who lack the opportunity to participate in the regional Science Caravan. Such children live in locations beyond the areas visited by the Science Caravan, and their villages often lack adequate funding to support participation in activities outside of the classroom.

In 2012, the NSM established a smaller scale version of the Science Caravan for these participants, called 'The Science Caravan – Red Route' or 'small-scale Science

Caravan'. The aim of this programme is to provide access to participants who would otherwise not have access to the traditional science caravan route in order to stimulate their interest in science. This caravan targets pupils aged 10-15, whereas most visitors of the Science Caravan are aged 7-18. The participant age range reflects the Ministry of Science and Technology's policy of stimulating young people in remote areas to become interested in science (National Science Museum Thailand, 2011). As mentioned above, the small-scale caravan travels to regions that are unable to access the larger caravan. The Science Caravan Red Route includes four science activities: the Science Show, Science Exhibition, Science Demonstration and Science Game. These activities are the same as those included in the main Science Caravan designed for larger groups. The activities take place in a host school over a three-day period; host schools are selected based on their location, specifically in terms of how easy it will be for other schools to travel to their site to access the caravan. Visitors attend the caravan as a school group. As the aim of this research (see 1.3) is to investigate informal science education in Thai regions and to focus on underserved participants in rural areas, the small-scale Science Caravan was identified as an appropriate opportunity for study.

1.3 Aims and research questions

The purpose of this research is to examine young people who may have limited access to informal science learning opportunities. This thesis addresses five research questions designed to study the settings and resources accessed for informal science education, factors affecting informal science learning, the needs of different informal science learners, and outcomes of participation in regional informal science activities.

The research questions are as follows:

(1) What settings or resources are available to young people for informal science learning at the regional level?

(2) What are the main factors affecting the experiences of Thai young people in informal science learning?

(3) How do informal science learning activities meet the needs of different demographic groups?

(4) What learning and other outcomes do young people obtain from participating in regional informal science activities?

(5) How can this learning be applied to other informal science communication projects at the regional level?

1.4 Structure of research

This thesis consists of 10 chapters, which are as follows.

Chapter 2: Literature review

This chapter reviews the context of the research, drawing on the relevant literature to discuss the relationship between informal and formal science education to promote scientific literacy, public understanding, and engagement in science and technology, including science communication. Chapter 2 also examines underserved participants in informal science learning and their access to opportunities. Moreover, it reviews science activities and science outreach programmes which support science learning for underserved participants.

Chapter 3: Theoretical framework

This chapter presents the research framework which is established from the examination of three main components, including the construction of knowledge, learning contexts and outcomes of learning. Constructivism learning theory is used to support the examination individual learning of learners and social interactions with learners during participation in informal learning activities. It includes the examination of learning behaviours while interacting in informal learning activities in relation to the construction of participants' knowledge. In contexts of informal learning, this study uses the learning model created by Falk and Dierking (2000) to investigate factors affecting learning in informal environments. The model also explores other informal learning experiences based on three contexts: personal, physical and sociocultural. Moreover, this chapter reviews learning outcomes in informal learning environments to promote the investigation of outcomes that local participants gain from informal learning engagements. The research framework is central in supporting an effective research design and methodology.

Chapter 4: Methodology

This chapter explains the study's methodology and research design. It presents the mixed methodology employed to collect data and details the development of the instruments for collecting data, sampling strategies and analysis of data. Additionally, it defines the research participants and settings and provides further context related to the Science Caravan. This chapter also explains the pilot study and relevant ethical issues.

Chapter 5: Participant information and available informal science learning resources

This chapter presents results on three main topics, participant demographics, the significant informal learning resources that promote science learning among local participants, awareness of the Science Caravan. These results elucidate research question 1 *'What settings or resources are available to young people for informal science learning at the regional level?'*

Chapter 6: Factors affecting Thai young people and informal science learning

This chapter presents factors affecting informal science learning experiences of participants obtained from student and teacher interviews results. The results of this chapter respond to research question 2 *'What are the main factors affecting the experiences of Thai young people in informal science learning?*'

Chapter 7: Informal science learning activities and learning

This chapter provides results pertinent to research question 3 '*How do informal science learning activities meet the needs of different demographic groups?'* Three main points are investigated; science knowledge background, the experiences of participating in the Science Caravan, and learning behaviours that participants demonstrated within the Science Caravan activities to obtain scientific knowledge. In this chapter, the pre-post questionnaire and the student and the NSM staff interviews are examined.

Chapter 8: Participation in regional informal science learning activities

This chapter offers the results that address research question 4 *'What learning and other outcomes do young people obtain from participating in regional informal* *science activities?'* Three main areas were found through investigation of the quantitative and the qualitative results: attitudes toward science and technology, learning outcomes from participation and the limitations and future needs for the Science Caravan.

Chapter 9: Discussion

This chapter consists of two main sections focused on the five research questions. For the discussion two main sections are presented as follows; discussion based on first four research questions; informal science learning resources at the regional level, factors affecting young people learning experiences in informal science learning, learning behaviours of young participant's interaction with these activities for obtaining knowledge, and outcomes of engaging with regional informal science activities in the Science Caravan. The second main section is investigating in this research and regards ideas of using the research knowledge apply to develop the other projects of a regional informal science communication.

Chapter 10: Conclusion and recommendations

This chapter presents conclusions as to factors affecting engagement in informal science learning amongst young people in Thailand, and the CCL model (contexts of informal learning, construction of knowledge and learning outcomes). Additionally, it proposes recommendations for implementation and future research.

1.5 Research outputs

This research has been presented in a number of science communication conferences listed below.

Conferences

- Triyarat, W., Wilkinson, C., Weitkamp, E. (2016). Results of a Regional Investigation with the Impacts of Science Caravan on Local Children. In the HAS Postgraduate Research Conference 2016. University of the West of England, Bristol, United Kingdom. 23 June 2016 (Oral presentation).

- Triyarat, W., Wilkinson, C., Weitkamp, E. (2015). Science, Young Thai People and Science Communication Activities in a Regional Science Caravan. In Science in Public 2015. The Science Communication Unit at the University of the West of England, Bristol, United Kingdom. 9-10 July 2015 (Oral presentation).
- Triyarat, W., Wilkinson, C., Weitkamp, E. (2015). Science Communication Activities and Young Thai People in a Regional Science Caravan. In the HAS Postgraduate Research Conference 2015. University of the West of England, Bristol, United Kingdom. 26 June 2015 (Oral presentation).
- Triyarat, W., Wilkinson, C., Weitkamp, E. (2015). How about: Taking Science to the Regions: Thai Experiences of Engaging Children through a Travelling Science Caravan. In Science and You Annual Conference 2015. University of Lorraine at the Centre Prouvé – Grand Nancy Congresses and Events, Nancy, France. 2-6 June 2015 (Oral presentation).
- Triyarat, W., Wilkinson, C., Weitkamp, E. (2014). Science Communication Activities and Science Learning in Young Thai People: Science Caravan (Red Route). In Evolving Science Communication: 10 Years of Science Communication at UWE 2014. Bristol, United Kingdom. 4 April 2014 (Poster).

Chapter 2
Literature review

Overview

This chapter explores the importance of literacy in science and technology, how it relates to the public and daily life, and public attitudes towards science. Additionally, it investigates science communication, public understanding of science (PUS) and public engagement with science and technology (PEST). It also examines science education in relation to the development of scientific literacy, including an examination of formal science education and its limitations related to science educational development. This review also considers the role of science communication in terms of informal science learning in promoting formal science education. It particularly points to science outreach programmes such as travelling science museums, defining their function and role in promoting the development of science learning amongst geographically remote populations. Finally, the chapter discusses the limitations of informal science learning as related to underserved participants in informal education.

2.1 Science and people

2.1.1 Scientific literacy

Science has an increasingly significant role in daily life and is an important part of today's society, influencing many contemporary intellectual and moral aspects of civilisation and forming an important component of worldwide culture (Stilgoe and Wilsdon, 2009: Brake, 2010; Osborne and Dillon, 2008; Hodson, 2003). Similarly, Thailand has a long history of dedication to scientific knowledge, and since 1917, the role of science and technology in everyday life and their role in promoting the development of the country (Klahan and Yuenyong, 2008), has acted as a foundation for economic progress (Laugksch, 2000). The application of scientific knowledge affects our work, contributes to healthier and longer lives, and allows for more convenient lifestyles with material comforts. Science supports the development of modern technology for use in industrial production, which contributes to the development of a country's economy (Wilsdon *et al*., 2005). Additionally, science provides essential knowledge to engage with many issues that people face in contemporary society. Therefore, an understanding of scientific practices and processes is identified as significant to modern life (Massey, 1999).

Scientific literacy is characterised by a knowledge and understanding of scientific concepts, processes and contexts, and it can influence individual decision making and personal participation in culture and economic affairs (Holbrook and Rannikmae, 2007). The basic arguments for promoting scientific literacy can be summarised into five points: (1) scientific knowledge supports people in making better political decisions, (2) understanding of science and technology can bring economic returns, (3) scientific knowledge can eliminate superstitions, (4) scientific knowledge can influence behaviour such as changing destructive behaviours to one's health and environment, and (5) applying scientific methods may lead to a more ethical society (Laetsch, 1987; Brake, 2010).

A lack of scientific literacy amongst the population has therefore concerned many international governments, and it is recognised as an obstacle to a country's development and international competitiveness with many countries increasingly investing in the scientific literacy of their population in order to reinforce economic development (McGregor and Kearton, 2010). Many developed countries such as the US have prioritised the development of scientific literacy in their educational approaches. The effective maintenance of economic and military security, as well as leadership in mathematics, science and technology have been related to scientific literacy (AAAS, 1994). Ryder (2001) stresses that the public should have scientific knowledge and understanding that is useful in the everyday context within today's technologically advanced society, as such knowledge promotes effective democratic decision making in scientific contexts (Ryder, 2001). Scientific literacy is therefore seen to also influence social judgments and the actions taken on issues involving science and technology in countries including Japan.

Kawamoto *et al*. (2013) suggest that improving scientific literacy in contemporary society is important for the determination of scientific policies which support effective national development. The development of effective science education is a significant strategy used to promote the improvement of scientific literacy

(Chalamwong and Pomlakthong, 2004). Although such strategies are not only focused on an improvement in educational standards amongst students, but also as applied to the wider population. Understanding scientific knowledge and engaging with science and technology development is increasingly seen as a way through which people may fully perform their role as citizens (Wilkinson, 2010). Scientific literacy has become a well-recognised educational goal worldwide, and symbolises what the general public should know about science (Durant, 1994; Jenkins, 1994), though scientific literacy continues to be debated in educational practice and scientific literature (Udompong and Wongwanich, 2014). For example there can be difficulties in creating international measures of literacy, difficulties in creating all-encompassing curriculums and making sure that literacy remains up-to-date with many emerging new scientific developments (Ryan, 2009; McFarlane, 2013).

2.1.2 Science Communication, public understanding of science (PUS) and public engagement with science and technology (PEST)

In addition to concerns regarding scientific literacy, attention has also been paid to perceived declines in trust towards science and technology first widely discussed around the period of the cold war. Developing scientific literacy and encouraging people to have more understanding of science was seen to be important from this era onwards in order to lessen distrust and misunderstanding of science and technology (Bauer, 2009). Furthering public understanding of science (PUS) became an influential decision-making factor in democracy and policy making, particularly in the UK in the mid-1980s (Miller, 2001). Similarly, in the US, informing the public about science was also recognised for its importance in relationships between science and society (Field and Powell, 2001). Developing PUS aimed to encourage peoples' interest and realisation of the importance of science and technology, which in turn was seen to play a role in changing attitudes (Bauer, 2009). This had implications for formal science education, as well as informal science learning and the role these activities were perceived to play in fostering peoples understanding of science and technology, as well as their interest (Royal Society, 1985; Bauer, 2009). Moreover, PUS aimed to encourage a wide range of audiences to be interested in science and technology, therefore also acknowledging the role of the mass media in promoting science and technology to the public (Field and Powell, 2001). Many efforts in communicating science to public under PUS in the 1980s and 90s, were seen to adopt a one-way communication approach, conveying science messages to public by speaking at audiences rather than encouraging audiences to have to a relationship with science in for promoting PUS (Irwin, 2009). There were limitations in communicating science to the public in this way including a lack of communication skills amongst scientists, sharing unclear information with the public and neglecting their concerns and mistrust in the power of science and technology. For example, implicit in the PUS agenda was the perception that the public was not positive enough about science and technology; there was a perceived danger that citizens had become negative or opposed scientific institutions (Bauer *et al*., 2007). This sense of public detachment and mistrust in science created an instinctive response amongst the scientific community to inform the public (Stilgoe and Wilsdon, 2009). Scientists were encouraged to communicate to the public directly about their field (Bauer, 2015), and many initiatives emerged promoting PUS on topics such as nuclear energy, stem cell research and energy policy all of which were topics that were matters of political as well as scientific concern at that time (Irwin, 2009).Communicating science via PUS was also then playing a part in national policymaking, whereby encouraging people to gain a better understanding and more knowledge, became tied up with an expectation that they would then become more positive with regards to science and technology (Treise and Weigold, 2002).

However, many issues were raised by this approach to PUS because of limited communication between scientists and the public and in some cases it was seen to stunt the public’s scientific literacy and lead to unclear understanding of science issues and even, in some cases, a negative attitude towards science (Bauer *et al*., 2007). The focus on informing the public rather than allowing the public to engage and present their own ideas and concerns led to disengagement, and at times scientists failed to tailor their messages to those they were communicating with (Wilkinson, 2010). There was also growing discomfort with certain scientific approaches, such as the bovine spongiform encephalopathy (BSE) crisis, the reaction to genetically modified crops (GM crops), and the concerns regarding the mumps and rubella (MMR) vaccine (House of Lords, 2000) in the UK. This meant areas of science and technology came to greater public attention, the perceived trust in science fell lower, and public attitudes towards science became far more ambivalent (Miller, 2001). Outside of the UK similar cases of controversies covered by the media were also identified as reducing the authority of scientific knowledge and scientists, such as the stem cell controversy in the US between 1975 and 2001 (Nisbet *et al*, 2003). Yet despite these apparent public concerns, about specific research and technological applications, people were also aware of the great value of science and technology in supporting contemporary lives in general and in specific areas such as nanotechnology (Forfas, 2012). Therefore, one-way approaches to communicating science from experts with knowledge to publics apparently without knowledge to promote PUS was not enough, and in some cases was also seen to increase the controversy of issues amongst communities (Trench, 2008).

To overcome the weakness of PUS in the past, developing communication skills of researchers and allowing people to have more engagement with science and technology has become important in fostering PUS (Wilkinson, 2010). More recent approaches seek to promote the creation of a scientifically engaged society as well as awareness of approaches that work less effectively (Trench, 2008; Stilgoe and Wilsdon, 2009).

Public engagement with science and technology (PEST) is now frequently found in policy making and in some cases occurring within informal contexts such as science museums and science centres (McCallie *et al.*, 2009). There are many reasons for encouraging public engagement nowadays. For example, engagement can capture public knowledge, encourage democratic principles, create more social knowledge and generate public funding. In addition, public engagement has been identified as a way to relieve potential controversy around emerging scientific issues (Wilsdon & Willis, 2004). Its methods often mirror the types of dialogic, participatory and contextual models of learning, which are often utilised in informal learning techniques. Over the last two decades, public engagement has successfully prompted the public to engage with science and technology. Complex ideas of engagement have emerged with various 'publics imagined', including an ignorant, anti-scientific public with too much concern and obstruction directed at science and technology (Owens, 2000).

PEST has therefore begun to be seen as increasingly important in relation to the credibility of science and technology (Stirling, 2008). PEST gives the public the authority to voice their opinion on science and technology issues. These opinions can help scientists and politicians to determine the development of science and technology and to make appropriate science policy in certain settings (Jung, 2009). However, at a day to day level in science communication, PEST also potentially allows people from many different backgrounds, in terms of their knowledge of science, to share their perceptions, notions, ideas and value-based responses regarding scientific questions and science controversy (McCallie *et al*., 2009). This engenders a two-way communication approach between scientists and the public (Bultitude, 2011). Tangible examples include permitting the public to share their comments and questions on scientific blogs, to share their ideas in science cafés and to discuss science during public lectures. In short, PEST allows the public to develop their perceptions of science. This two-way communication can potentially raise the effectiveness of communication between the public and scientists or politicians, leading to clearer and improved communication mechanisms (Wilkinson, 2010) around topics such as nanotechnologies, climate change, the environment and health (Murphy, 2013, Pang *et al*., 2003; O'Neill and Nicholson-Cole, 2009). Nowadays, science communication frequently adopts a 'dialogue model' that allows publics to be more engaged in two-way communication, also based on their own knowledge and experiences (Trench, 2008).

In Thailand, public engagement is also being used in the Thai context, to debate topical scientific issues. For example, the Thai government, via the National Science and Technology Development Agency (NSTDA) is an institution primarily responsible for generating Thai public engagement with scientific topics. For example, the NSTDA established a public awareness of science and technology project for 18 months in order to encourage Thai people to be aware of the importance of nanotechnology. This project aimed to encourage Thai people to share their knowledge and understanding, including their needs from scientists or researchers, in order to promoting effective policymaking surrounding nanotechnology development and promoting the countries development in this scientific field (Cientifica, 2012). Whilst a number of countries, including the US and the UK, are also attempting to use the 'Upstream' model of communication to frame public engagement which involve scientists and various publics at an early stage of decision making (Kearnes, 2006), and these are frequently complimented with other formats for two-way communication such as science cafés, blogs, websites, science fair and informal science learning (Bowater and Yeoman, 2013; Stocklmayer *et al*., 2001)

In the new era of public engagement for the younger generation, informal science activities and events for public engagement have included informal science activities for schools, visits to informal learning settings, discussion via traditional and online media, pubs, festival and cafes. It can be seen that informal science activities are gaining more influence in promoting the public's scientific literacy and understanding, which in turn endorses democracy and policymaking (Gura, 2013). These informal activities are sometimes critiqued for replicating existing power relationships between scientists and the public (Haklay, 2013). However, these activities have nonetheless become more popular for encouraging public engagement with science and technology, particularly among young people (Saikkonen and Valiverronen, 2014). In the UK, the government is working particularly hard to develop PEST amongst young people through informal science activities such as engaging in science centres, science museums, zoos, and other informal science learning environments with the long-term goal to promote public engagement (Dawson, 2012). Likewise, the US government is contributing to PEST amongst young people via informal learning environments and advocating the development of the nation's educational institutions to produce literacy in STEM (Science, Technology, Engineering and Mathematics), with the long-term goal of producing future employees in these areas in order to enhance the US' economic competitiveness (U.S. Department of Education, 2007).

Moreover, in Asia, governments are considering prompting public engagement with science and technology via informal learning settings, such as science museums, science centres and zoos, to develop the science potential of the population. For example, Taiwan's government is attempting to encourage its population to visit science museums, where the number of visitors has continuously been increasing since 2008 (Shein *et al.*, 2015). In Thailand, promoting engagement with science and technology among Thai young people via informal science activities, such as discussion through media, science comedy shows and events at science cafés has begun creating public awareness in areas of science such as health. For example, the threat of malaria and other tropical diseases have also promoted the development of scientific literacy and understanding among Thai young people (MORU, 2016).

Settings such as science museums and centres also provide useful contexts for such discussions and for promoting science learning amongst young Thai people (Kanhadilok, 2013). Chimmee (2016) for example designed a learning package based on problem-based learning as part of Sexual Health Exhibition at the NSM. She found that young people who engaged with two-way science communication in these activities gained better understanding. Similarly, Ditsomboon (2016) also developed a two way learning activity via Facebook focussing on Scientist's biographies to encourage children to become interested in science careers. Her activity used inquiry-based learning to stimulate the children involved to ask questions. She also found that children became more interested, visited the page, and wanted to find out more information, when they could enquire compared with the provision of only information without an opportunity to ask questions. Participation in informal science learning is increasingly recognised as an important part of encouraging Thai people to engage with science and develop their science skills and knowledge (National Economic and Social Development Board, 2011).

Therefore, in developed areas of the world, PEST plays an important role in supporting policy making and developing science and technology. On top of this, it is a major part in creating a positive attitude towards science in the public in order to create a science society for the sustainable development of the country.

2.1.3 Science education

Science education lays the foundation for a scientifically literate society, and informs public attitudes towards science and technology (Wilkinson, 2010; Trefil, 2008; Sjøberg and Schreiner, 2010; Stocklmayer *et al*., 2010). In developed countries such as the US and the UK, educational policies focus on the effective development of science education to provide adequate knowledge, awareness of the importance of science and the nature of its relationship to the development of the nation to young people (Osborne, 2013; U.S. Department of Education, 2007; Stocklmayer, 2010). Formal science education is used to provide a fundamental base of knowledge; in schools and universities people learn about theories, as well as concepts including epistemology and the methodologies of science. One of the drivers for these educational policies is the need to produce suitable numbers of scientifically trained young people willing to take up careers in science; if inadequate numbers are produced, countries may become disadvantaged both economically and democratically (Lewin, 2000; Brossard *et al*., 2005).

Many developed countries such as the US, the UK and Australia have realised the significance of STEM's interdisciplinary qualities for the development of young people's scientific performance, and how they apply their knowledge to the real world. Thus modern curricula are designed to highlight the interdisciplinary and collaborative nature of science (Mulnix, and Vandegrift, 2014). Additionally, DeBoer (2000) suggests that the overlap between science and technology in relation to social life, and creating science-career based opportunities for students is also important for the development of science education.

However, there are limitations of science learning in school. These include teacher-led classroom activities when the scientific knowledge of teachers can be highly variable, particularly at primary level. Students must learn compulsory curriculum with formal assessment and therefore there can be tendencies to 'teach to the test'. There is little choice in regard to what they want to learn, and the lack of science equipment in classrooms can be all negative factors that obstructed science learning of young people (Wellington, 1990). These limitations on science learning in classroom may cause young people to avoid science subjects once they are no longer compulsory (Kawamoto *et al*., 2013).

Over a number of years it has been noted that fewer young people seem to be interested in science and technology (Miller *et al*., 2002: Osborne and Dillon, 2008) and declining numbers of students pursuing scientific subjects has been linked to their attitudes and poor performances (Tytler and Osborne, 2012). Lyon's (2006) study, found students often have poor attitudes towards science and find it boring because it's difficult to understand. Hence, students often prefer non-scientific subjects. Science classes too often fail to make science personally meaningful or relevant, for instance widely differing enthusiasm or interest from different teachers may cause students to avoid participation in science classes (Ruggs and Hebl, 2012). Furthermore, the relationship between interest and desire for a career can differ. Wulf *et al*'s (2010) survey showed that most students 'strongly agree' when asked the question 'do you like science' when participating in informal science activities, but most of these students do not want to pursue a career in science, because of the difficulty of science in school. Many students agreed that science subjects are difficult to understand, especially physics (Aikenhead, 2006). Therefore, students who want to further pursue science courses and careers are students who do well in science classes and have planned to study science rather than incidentally registering to study a scientific subject (Osborne *et al.,* 2003). The investigating science capital (science-related forms of social and culture capital) from surveys conducted in England, and completed by students from schools generally serving more disadvantage populations illustrated science in school and out of school are importance primary spaces to encourage children engage with science. Additionally, parents and other people encouragement's and sharing intentionally interest or values that they have for science has impact on young people making decisions to continue with science (DeWitt *et al.,* 2016)

Nowadays, science education developers have considered using informal science learning to promote formal science education and improve the level of interest in science and the scientific performance of young people (Wellington, 1990). For example, free-choice learning such as science museums (Falk and Dierking, 2012), science outreach programs to encourage girls' interest in STEM (Watermeyer, 2012), and using informal learning activities to promote science education such as science debates (Murphy, 2008) are all techniques which have been utilised. Furthermore, factors affecting classroom science education such as gender, individual interest, poor performance and attitudes towards science from young people are being considered to develop effective informal science learning and meet the needs of young people. Increasing the number of science students should increase those working in scientific fields (Wellington, 1990) though some argue the 'science pipeline' to be more complex (Osborne and Dillon, 2008). Thus, informal science education plays an important role in promoting people's interest in science, developing scientific performance and improving student success in science education (Falk, 2001).

2.2 Informal science learning

2.2.1 Definition of informal science learning

Informal science learning is any activity involving scientific understanding, knowledge, or skills development that occurs without the presentation of a formal education curriculum (Livingstone, 2006). According to a review of informal science learning carried out by the Wellcome Trust in 2012, informal science learning is non-compulsory or free-choice learning which takes place outside of the formal curriculum. However, informal science learning is able to reinforce formal education. For instance, in an investigation of classroom-based reproductive and genetic technology debates amongst Irish students, Murphy (2008), examines the role of the films *The Giff (1999)* and *If… Cloning Could Cure Us (2004)* shown to students before a debate. These students made their assumptions related to their knowledge and experiences outside of school, and used this information to support the points of their debate. Informal science learning settings and resources can include many opportunities beyond the media. It can include science centres, museums, zoos, an individual's home or any public space. Other forms of science learning outside the classroom can also consist of media sources, such as a television programmes, books or online engagement (Phipps, 2010).

2.2.2 The significance of informal science learning

Many advantages of informal science learning have been noted. It encourages a positive attitude towards science, and inspires participants to learn what their personal interest may be in a relaxed environment (Kelly, 2000). Moreover, the experience of learning in an informal setting has also been found to motivate learners to be interested in science and to lead to future enquiry and enjoyment of the field (Dori and Tal, 2000). Learning science in informal environments may therefore make a significant practical contribution to society (Bell *et al.,* 2009). Participation in informal science learning allows many people from different backgrounds, including scientists, to learn science and share ideas together and scientists also have the opportunity to interact with the public during such activities and events (Falk and Storksdieck, 2005; Schwan *et al.*, 2014). Therefore, learning in science museums and centres, science festivals, and science demonstrations extends the educator role and encourages direct interaction between scientists and the public (Braund and Reiss, 2004).

Over the past several years, learning science in informal environments is developing a significant role in supporting learning in school, and it has also come to influence the decision making of young students about appropriate subjects to study in further education. The UK Association for Science and Discovery Centres (2011) indicates that 25% of 3666 first-year university students in one study said that science centres and museums were ‘important or very important’ in their decision to take STEM courses. Moreover, the US is now concerned about the challenges presented by the fast growth of STEM talents in Asia, chiefly China, given that students in the US have shown little change in their pursuit of STEM studies and careers. Therefore, many states in the US have launched campaigns in order to increase the number of students in STEM and to promote science centres and museums as effective tools to broaden interest in STEM (Thomasian, 2012).

2.2.3 Learning science in informal learning environments

In recent decades, many countries have been attempting to use informal learning to support formal learning and increase individual motivation to learn in order to further the development of the scientific potential of their population (McCombs, 1991). According to Bell (2009) and others mentioned in ‘Learning science in informal environments’, learning science in informal environments means learning science beyond the everyday formal curriculum in educational institutes. Bell (2009) and other identified four venues or configurations for learning taken into consideration in this work; (1) everyday learning experiences such as learning from family members, (2) designed environments such as science centres and museums, (3) after-school and adult programmes such as science clubs and cafés, and (4) science in the media such as information found on radio, television, internet, and published media. These configurations are settings in which people can obtain knowledge outside of formal learning. Bultitude (2011) states that are slight differences when considering ways of obtaining knowledge based on science communication media. According to Bultitude’s work, there are three main venues through which the public can acquire science information and knowledge: (1) obtaining knowledge from online and traditional publishing and broadcasting such as newspapers, films, television, and radio, (2) participating in live or face-to-face events such as science cafes, science centres and museums, and science festival, (3) online interaction such as blogs, social networks and science games.

Learning science from traditional publishing and broadcasting has advantages in that many audiences can acquire knowledge at the same time through viewing or hearing a television or radio programme (Salager-Meyer, 2008). There are many high-quality productions made by professionals (Meneghini, 2012), and the audiences can choose to adopt media to support their personal interests, learning styles and preferences. Examples of this include learning science from science television programmes, books or a science-related newspaper article, and conversations with friends or family members (Valle and Collanan, 2006). One disadvantage, however, is that scientists themselves often lack control over how the media covers their research, and most of these media offer only one-way communication of the information in which the science is limited to the basics (Van Dijck and Poell, 2015).

Learning science from online media can also serve a large audience. Millions of people can access the events and connect to scientists, but these media offer limited opportunities for two-way communication though they do have the added benefit that the audience can access these forms of media any time they wish (Torres-Salinas *et al.*, 2011). Moreover, a smart phone can be used to access online scientific content in less economically advanced countries. These resources may support science learning in school, reducing limits of accessing informal learning settings which may be far away or costly (Pimmer *et al.*, 2012). However, as most online media presents general information, controversial topics can be poorly addressed or limited to pseudoscience (Clark, 2015).

Designed settings such as science centres and museums provide appropriate learning activities and environments that encourage visitors who are interested in scientific content to participate in exhibits, science outreach programmes and public lectures (Falk *et al.*, 2014). On top of this, designed settings also provide environments which stimulate people to engage and create public awareness in science and technology (Bell, 2014). In science centres and museums, visitors have a chance to interact with activities, staff members and other audience members directly, thus providing two-way communication (Kamolapattana *et al.*, 2015) where the experts and the audiences can be involved by offering complementary areas of expertise and deepen conversations which lead to knowledge acquisition. In Australia, Packer and Ballatyne (2002) present a study on the relationship between motivation and learning in 250 visitors (81 museum visitors, 88 art gallery visitors and 81 aquarium visitors). The researchers found that during their visit to these places, most respondents (42%) expressed enjoyment in visiting aquariums. For museums, education was the most popular answer from the visitors (45%), who visited museums with a view to gaining knowledge to support education. In an art gallery, most visitors (41%) indicated that they gained motivation and inspiration. Likewise, learning outside of school via a zoo context in Taipei was also seen to influence people's participation in zoo activities and develop their learning. In Lai's (2012) study, zoos are identified as a place to support teachers when teaching about animals and biology. Lai's (2012) investigation illustrates that 92% of 1,233 participants were satisfied with one trip and 51.6% obtained a greater understanding of animals. Furthermore, Gerber *et al*., (2001) asserts that the formal classroom is not the only place which supports student science learning. Learning in informal environments also motivates children to become interested in science, and teachers may use these venues to help their students find answers to science questions that arise from student individual interest. The atmosphere of freedom and independence provided by informal learning settings has been identified as encouraging willingness to learn science. For example, the 'playfulness' of science museum activities has an influence on learning development and better mental health. Kanhadilok and Watts (2014) investigate science learning with traditional Thai toys in the Science Museum of Thailand and found that many participants were happy to do the activities, and the activities encouraged people to share their ideas and help each other in a playful atmosphere. Play-based learning may help students learn science willingly and promote science learning development.

Promoting science learning with informal science learning activities engagement is useful supporting for science learning in schools for young people.

2.2.4 Informal science learning activities for promoting learning in informal environments

Informal learning activities have an important role in promoting knowledge attainment (Bell, *et al*., 2009), and these activities are often designed to promote learner understanding of current issues or significant knowledge so that learners may actually retain information rather than focusing on an abstract task (Salmon, 2013). Informal learning venues and activities also are free-choice learning promote learner learning and obtain and construct their knowledge and understand from participating (e.g. visiting museums) (Falk, 2005).

Previous literature suggests four main activities are common in informal settings including, experiments or laboratories, shows on stage, hands-on exhibits, and games (Bell, *et al*., 2009; Watermeyer, 2013; Kanhadilok and Watts, 2014; Braund and

Reiss, 2004). ‘Science experiments’ are useful scientific activities that support participants in developing greater facilities in scientific language. Terms like hypothesis, experiment, and control begin to appear generally in discussion of what they are learning, and non-scientists begin to gain entry into the scientific culture and community through these experiments (Fenichel *et al.,* 2010). Science experiments can be quite useful to verify scientific principles, promote the development of problem solving skills based on the scientific method, and support cognitive construction (Kirtikar, 2013). ‘Science shows’ or ‘science demonstrations’, on the other hand, present the mysteries of scientific theories, especially physics phenomena presented for example as a “Magic Show” (Lachapelle, 2009). Science shows are often used to attract participants to science exhibitions and are among the most popular activities which attract audiences who are interested in natural science (Watermeyer, 2013). ‘Science exhibitions’ or ‘hands-on exhibitions’ are effective tools that help science teachers, as students are able to learn by themselves. Exhibitions can combine the involvement of learners with scientific research demonstrations (Sleeper and Sterling, 2004). Hence, exhibitions are often the main element in museum contexts which encourage children to learn alongside their parents or family members (Falk and Storksdieck, 2005). ‘Science games’ such as puzzles, quizzes and toys are useful in supporting education based on entertainment and enjoyment. The main purpose of games is to encourage willing participation and to allow people to play with and practise their skills in a non-threatening environment (Hromek and Roffey, 2009; Kanhadilok, 2013). When designing learning activities, it is important to consider how these activities promote learning the information being communicated. The characteristics and points for promoting learning for the four activities are presented in Table 1 according to suggestions provided by Allan (2007), Falk and Storksdieck (2005), Hromek and Roffey (2009) and Lachapelle (2009).

Table 1: Sample of informal learning activities

Activity	Characteristics	Promoting learning
Experiment	• Designed for a small group rather than a large group or individuals. • Allows audiences to learn science through action.	• The audience gains self-esteem by doing the work themselves. • The audience can use their skills and experience to do

	• Forces audiences to find the answers to an experiment problem either by themselves or via group work. • Demands idea sharing in group work. Audiences must demonstrate their ideas to each other. • An explainer gives some information to encourage the audience do the activity.	the activity. This encourages the audience to brainstorm and share ideas in their group to find out the answer. • Enables individual audience members to apply their knowledge and skills to a complex problem and encourages information sharing.
Show or demonstration	• A demonstrator demonstrates a particularly interesting, exciting scientific phenomenon or scientific theory.	• Attracts more audiences. • Incites excitement and enjoyment. • Permits the audiences to explore science issues in the show. Audiences can share ideas and experiences and construct their knowledge. • Focuses on current science issues. • Discussions are lively during the show. • Involves all learners.
Hands-on exhibits	• Audiences interact with the exhibition. • Demonstrates scientific knowledge in an interesting and attractive way. • Makes science phenomenon easy to understand and link with daily life. • Permits audiences to learn by themselves or through sharing skills and experience with each other or the explainer. • Permits audiences to touch and test to help them understand the exhibition content. • Explores different perspectives.	• Encourages the audience's interest in science. • Encourages learning skills development. • Increases social experiences. • Applies knowledge background in science learning. • Develops ideas. • Encourages excitement and enjoyment (play).
Games (toys, quizzes, puzzles)	• Designed for an individual, small group or large group work. There are many questions that help the audiences learn particular science topics or broader theories. • Challenging activities that encourage audiences to find answers by themselves or by sharing knowledge	• Useful for assessing audience's knowledge. • Encourages the audience to be involved with science through enjoyment. This activity can be highly motivating. • Can add some excitement

	in group work. • Audiences must complete or otherwise sort out problems in mathematics or science puzzles, etc.	through the game aspect and provide feedback to the science explainer who runs the activity.

Note: adapted from Allan's sample learning activities (2004): Falk and Storksdieck, 2005; Hromek and Roffey, 2009; Lachapelle, 2009

This variety of activities for learning in informal environments demonstrates how scientific knowledge is acquired from interacting in informal learning activities in science outreach programmes many of which can be designed to complement or have varying effects when compared to others within the same exhibition or space.

2.2.5 Informal science learning outreach and informal travelling science museums

'Science outreach programmes' is an umbrella term for a variety of science activities from academic institutes such as research institutes, universities, and science museums and centres. The aim of science outreach programmes is often to promote public science awareness and understanding and to make an informal contribution to science education (Varner, 2014). For example, in the US, Informal Science Education Institutions designed a specific programme, called the Urban Advantage programme, to align with the middle school science curriculum for New York City schools. This programme aims to increase student science scores and potential for science learning in order to support the policy of increasing the number of employees in the science sector in the 21th century. This programme provided five main activities to promote science learning for the US students; professional development for teachers, students completing long term science investigations, the provision of informal science learning resources for teachers and students, leadership institutes for school-based science leadership teams and leading science teachers, and an outreach science program to promote families science learning (Weinstein *et al.,* 2014). Moreover, in Kansas, a science outreach programme which involves learning with NASA's 'Robot Roadshow Program' was shown to benefit Kansas students' science learning by providing access to science resources which would otherwise not be available to them. This project focused on applying interactive experiments. These students came from small schools, some with only one classroom, which had less money to support science learning with fewer or no opportunities to engage with any informal science learning institutes. (Matson and DeLoach, 2004). In a further example, the UK Centre for Materials Education funds an after-school Science Workshop for 11 to 15-year-old girls in Brixton through the Baytree Science Club Project. This project aims to extend opportunities to access science through interactive science learning, particularly for ethnic minorities and children from disadvantaged social backgrounds. This science club also took four girls to Gatwick to participate in the National Final of the BAA Challenge/Young Engineers Competition, a contest involving other groups from schools across the country (UK Centre for Materials Education, 2011) once again providing opportunities which may not otherwise be available to the selected students. Weitkamp and Arnold (2016) highlight the importance of working together with teachers in the design and development of science outreach programmes. In their study of a genetics outreach programme, Weitkamp and Arnold (2016) found changes in knowledge and attitudes toward genetic modification (GM) technologies as well as an increase in interest in the relationship between science and society.

Like outreach programmes, travelling science museums provide hands-on exhibitions, including science activities, to participants who lack the opportunity to visit a museum, assisting students in developing their scientific knowledge and skills (Varner, 2014). The main aim of travelling science museums is often to encourage participants to gain a greater understanding of the curriculums of science (Badger and Harker, 2016). For example, in the US, Western State Colorado University developed a travelling science museum in order to encourage student interest in science with the concept that 'everyone can do science'. This activity has served at least 20,000 students each year. The exhibits are set up in two classrooms, and students spend 45 to 90 minutes engaging with them. From these events, participants have been recorded as having a positive attitude towards activities, and as having gained scientific knowledge related to the formal curriculum (McMeeking *et al.*, 2016). In Australia, the Shell Questacon Science Circus is a travelling science exhibition that has promoted science education since 1997. This project was established from a collaboration between Questacon, Shell and The Australian National University. The circus, which travelled across Australia entertaining the crowds en route, reached a quarter of a million people in 2000 and played to 100,000 young people at schools in six tours (Bryant, 2001). Travelling science museums serve people, especially those who cannot access other informal science learning institutes because they are far away from these institutes, by bringing science outreach activities to these locations (Badger and Harker, 2016). The Science Caravan falls into this class of science outreach or travelling science museum, seeking to extend the opportunity to access informal science learning to those otherwise unable to participate in such activities by virtue of the barriers of distance and cost.

2.3 Underserved participants in informal science learning

The ideal of science for all promotes the perception that everyone can learn science in informal environments and such science activities are provided so that everybody, in principle, can access these settings (Wellcome Trust, 2012). In fact, most students who engage in informal science learning settings come from middle class and wealthy backgrounds, live in urban areas and visit such environments with family or their school (Bell *et al.,* 2009). Some people may avoid participation in informal science learning because they come from minority groups and low-income backgrounds, such as immigrants who face language barriers (Dawson, 2013). For example, refugees in the UK may face limitations in their English which limits their engagement with informal learning settings. This factor has an effect on the decision to avoid involvement in such activities. Further, often participation is not simply about economic cost as in fact there are many informal learning settings which allow groups access without payment, such as museums (Dawson, 2014). The research on visitors to informal learning settings in the UK suggests that a huge number of the population, including those from minority ethnicities, socioeconomically disadvantaged backgrounds and local areas feel that informal science learning settings are ‘not for them’ (Dawson, 2012; Dawson, 2014; Lee and Luykx, 2007). Similarly, in China, where the government is attempting to develop scientific literacy, and many studies show that interest in technology and innovation-based STEM has increased rapidly in the past three decades (UNESCO, 2010) similar barriers to informal engagement has been found. The Chinese government has been seeking to stimulate people to be more engaged with scientific knowledge by building a local science museum in each state. Unfortunately, people in each state have different characteristics, and there are many minority groups. Thus, some content of the local science museums may be hard for different sociocultural groups to absorb. As China's government is concerned about the public not participating in informal science learning, investigations of the nation's different sociocultural groups and non-participation are now being considered (Donghong, 2015).

In the US, learning science in informal environments such as science museums also plays an important role, when the average young Americas spends less than 5% of their life in classrooms, with most science learning occurring outside of school (Falk and Storksdieck, 2010). However, factors such as being a part of minority groups, a low-income background and location where you live has also been recorded to influence engagement in informal science learning (Dawson, 2014). Similarly, in Japan, although a large portion of the population has an advanced understanding of scientific knowledge, those who may not participate in science activities also face obstacles in accessing science information due to residing in locations which are seen to be too far away (Miyamoto et al., 2015).

Although some participants may have a positive attitude towards science and may consider science careers, they may then have limited access to scientific knowledge that could inspire them and may decide to turn away from science careers they would otherwise consider pursuing (Atwater *et al.,* 1995). For example, in Upadhyay's (2009) investigation it was found that Hmong students could not understand how cancer related to cellular malfunction because the knowledge foundation they developed from communities, families, and individuals was different from US urban students' knowledge foundation and was not complimented by additional or alternative sources. Upadhyay highlights the need to provide appropriate learning materials and activities to encourage this group to continue to be involved with science learning beyond the community in which they live (Upadhyay, 2006). In Thailand, young people who have limits to their involvement in informal science learning mainly have low-income backgrounds, live far away from informal learning settings, or study in the low-performing schools that lack funding to promote extracurricular science education (see section 1.2.6 in Chapter 1) (Tumtong, 2014) thus similar issues are likely to be present.

This study defines underserved participants by combining the characteristics of non-participants who avoid involvement in informal science learning because of their sociocultural backgrounds and those who want to engage in informal science learning but lack opportunities for involvement. In the US and Canada, underserved participants are considered to be those in social positions such as an ethnic group, social class or financial status, who experience difficulties in accessing informal science learning, in some cases this is combined with a lack of local provision of such opportunities. These factors play significant roles as barriers to participation in informal science learning activities. Similarly, in the UK, ethnicity, class and financial limitations are considered factors that limit involvement in informal science learning (Aikenhead, 2002; Fenichel *et al*, 2010; Jones, 1997; Dawson, 2013). Therefore, race, ethnicity, minority status, immigration, speaking in a different language, gender, and coming from a low-income or socioeconomically disadvantaged group can all limit ability to participate in informal learning settings. This research assumes this all-encompassing view in its consideration of underserved participants.

To provide informal science learning for all, an understanding of how participants are underserved can be vital to increasing opportunities (Lee and Luykx, 2007). This is because learning science outside of school via contemporary learning opportunities is a main predictor of child development in the subject (Falk and Dierking, 2010). Investigating the role of underserved participants in informal science learning is likely to be important for many countries in order to support the development of nations, governments should make efforts to understand more concerning their various underserved populations (National Science Foundation, 1994).

Chapter summary

This chapter examined scientific literacy, science communication, PUS, PEST, science education, and informal science learning through science outreach programmes and travelling science museums. It also included an exploration of those participants who may be underserved in terms of informal science learning.

The relationship between science and the public is important in terms of supporting everyday life, economic development and democracy. Scientific literacy and understanding, including public engagement with science, influences the development of nations. Science education has played a significant role in supporting increases in science literacy. Additionally, science communication also is important for promoting PUS and PEST. However, limitations in traditional science education particularly affect young people's interest in science. Thus, informal science learning is a supporting strategy which encourages students to nurture their interest in science and technology with the hope that they continue studies in the field and can encourage students to become more interested in scientific knowledge. However, informal science learning is not available for all. Some young people lack the opportunity to participate in informal science learning because of their background, such as having low-income families, language barriers, or spatial difficulties in accessing informal learning institutes. Travelling science museums or outreach science programmes, therefore, are essential options for promoting scientific knowledge for remote or underserved populations. Participation in travelling science museums or outreach science programmes can potentially stimulate the interest of underserved participants and allows them to gain more science knowledge related to the science curriculum in their schools.

Chapter 3
Theoretical framework

Overview

This research intends to examine the relationship between learning contexts and learners who construct knowledge from informal learning experiences.

This chapter comprises four main sections. Firstly, it explores constructivist theories in regard to cognitive and social constructivism, the VARK model (visual, audio, reading/writing and kinaesthetic) of individual learning, and learning through social interaction, via the visitor engagement framework (VEF). Next, the chapter presents the contextual learning model of Falk and Dierking (2000) and its three main contexts: personal, physical and sociocultural. In the third section, learning outcomes that participants obtain from informal learning engagements are investigated, primarily through examination of generic learning outcomes (GLOs) (Brown, 2007), including (1) knowledge and understanding, (2) skills, (3) attitudes and values, (4) enjoyment, inspiration, and creativity, and (5) activity, behaviour, and progression. By reviewing these approaches, the theoretical framework of this study is presented in order to support its approach, aims and five research questions in the fourth and final section.

3.1 Learning in informal environments

Learning is a lifelong and complex process of change in an individual's knowledge, skills, attitudes, beliefs, feeling and concepts (Hein and Alexander, 1998). Learning is as essential and fundamental as being alive. It is one of the principles of mankind, and something that separates us from other living species (Claxton, 1999). The process of learning takes place in physical, personal and social contexts (Falk and Dierking, 1997). Consequently, it incorporates recognition of the importance of prior experiences and knowledge, the individual nature of knowledge construction, learning alternatives and social interaction (Gilbert and Priest, 1997). Learners use their learning experiences to promote the construction of new knowledge and develop their skills and attitudes (Kolb, 2015), whilst social interaction also has an impact on learners' construction of knowledge (Anderson *et al.*, 2003).

Learning in informal environments, as mentioned in Chapter 2, is defined as learning outside of school and in everyday life in informal environments such as museums, zoos and aquariums. Learners can learn alone or through involvement with others. In contrast, formal learning takes place in school and is associated with formal curricula and assessments. In such cases, teachers are the main instructors for students' construction of knowledge (Stockmayer *et al.*, 2010).

3.1.1 Learning theories in informal learning: constructivism

In constructivism theory, cognitive and social constructivism are the two essential components which build learning based on individual development through cognition and social interactions.

In cognitive constructivism, based on a theory by Jean Piaget, this learning theory focuses on what goes on 'inside the learner's head, and how the learner develops a cognitive approach by focussing on mental processes. Knowledge is constructed by learners based on their existing cognitive structures. Learning is related to a learner's process of cognitive development and understanding, and their existing intellectual framework is central to understanding the learning process of learners (Berkeley Graduate Division, 2017). Cognitive constructivism was a fundamental theory used to support a later theory that argues that the learning process is an equilibrium between learner and the environment through assimilation and accommodation processes, which emphasises how knowledge is constructed on behalf of the learner (Wadsworth, 1996; Tryphon and Vonèche, 1996).

On the other hand, social constructivism is the development of a learner's cognition through social interaction (Van Der Veer, 2007). Social constructivism emphasises the role of society and culture in shaping individual perception and attaching meaning to experiences (Jordan *et al.*, 2008). Vygotsky studied student learning in classrooms. He argued that Piaget's learning model is an individualised perception of cognition, ignoring for instance the role of teachers in the promotion, construction and expansion of students' knowledge (Gauvian and Cole, 1997 and Daniels, 2008). Vygotsky, thus, introduces the zone of proximal development (ZPD) to explain the difference between what learners can retain on their own, without support from others, and what they can achieve with social support. There are three zones of learning in ZPD, as learners can absorb information alone, with guidance and not at all. In ZPD, the facilitator or guide such as a teacher, coach or explainer enables learners learning, so learners can access material and learning that is beyond what they could access alone. Learner cognition expands what is known as the ZPD, meaning that the zone includes both what is individually known and what is not (Daniels, 2008).

Constructivist theories have had a significant influence on contemporary science and mathematics education, as well as literacy, arts, history, and social science (Matthew, 1997; Cobern, 1993; Gil-Pérez *et al.*, 2002). Additionally, constructivist theories have been used to observe the education of learners in informal learning settings in relation to their construction of knowledge. For example, it is a multi-faceted experience which encourages visitors to interact with activities in museums. As mentioned above, visitors can learn on their own, or they can share ideas with their family or instructors (Jeffery-Clay, 1998). Stroud (2008) investigated teaching and learning science in museums based within a constructivist framework. He finds that society in the form of explainers, teachers and friends have an influence on student learning. His study showed students construct their knowledge from social interaction by asking explainers or teachers and sharing ideas with fellow students, in a similar way to science learning in school, where teachers take the role of helpers who assist students in learning science in the classroom (Garbett, 2011). In addition, museums provide active learning activities, which stimulate visitors to develop their individual learning skills. They can learn and construct their knowledge by themselves from individual interaction with activities and exhibits (Hein, 1999). Thus, based on cognitive and social constructivism, museums potentially provide an informal learning environment that is essential to developing learning skills both individual and with others (Eshach, 2007).

Using constructivism to investigate learning in informal environments can allow for the preparation of appropriate learning activities for optimal comprehension, retention of information, and collaboration with others. Well-situated learning activities help learners to link knowledge to their daily life which stimulates them to realise the importance of learning (Bednar *et al.*, 1995). Therefore, this research uses cognitive and social constructivism as one basis to investigate the outcomes of learning in the informal environment of the Science Caravan.

3.1.2 Learning behaviour: learners' interaction in informal learning environments

Learning behaviours are interactions with learning activities and other learners in formal and informal environments to acquire knowledge or deepen understanding (Pritchard, 2009). Moreover, learning behaviours have been examined to identify styles of learning in order to define an individual's characteristics of organising and thinking about information (Fleming and Baume, 2006). In informal learning, such as learning in museums, visitor behaviours as they interact with exhibits and activities help visitors' process information for the construction of new knowledge (Lehn *et al.,* 2001). Additionally, Heath *et al* (2005) consider social interactions such as collaboration, competition and sharing to investigate learner behaviours and how they interact with each other to gain knowledge. Likewise, this examination uses visitor interactions with activities in the informal learning setting of the Science Caravan in order to define learning behaviours in relation to the construction of knowledge from participation.

Neil Fleming developed the VARK model to examine the behaviours of learners as they interact with learning activities. The acronym VARK stands for visual, aural, read/write and kinaesthetic learning styles. Visual learning absorbs information by seeing and watching, aural by listening, read/write styles focus on learning from reading or writing information, and kinaesthetic learning is obtained by physically performing actions (Leite *et al*., 2010; Hawk and Shah, 2007). The VARK model is used extensively in examining learning styles in informal and formal environments (Ainsworth and Eaton, 2010). However, social factors play a lead role in informal education activities such as science museums and science centres (Kanhadilok, 2013), whereas the VARK model particularly focuses on individual learning behaviours, which may or may not link to social interaction factors. This research considers that both individual learning and social interaction are important in understanding how learners construct knowledge from informal learning experiences, as these experiences incorporate both individual and social factors.

The visitor engagement framework (VEF) is a guideline used to investigate visitor interaction with informal learning activities. The framework, similar to the VARK model, has four basic learning behaviours, but the VEF considers social interaction and how visitors interact with each other in relation to knowledge construction. Therefore, this research considered this framework to determine the relationship between individual knowledge construction and social interaction.

The visitor engagement framework (VEF) was developed by Barriault in 1998. Since then, it has been used for investigating visitor interaction or learning behaviour during engagement with informal activities in museums (Talbot-Smith *et al.*, 2013). This framework is generally used for wider groups of visitors who interact with activities in informal learning settings, such as families or students on school field trips. Staff, educators and researchers use the VEF to observe visitor interaction with activities and exhibits in science museums or other informal learning settings (Leister *et al.*, 2015). An investigation tool, the focus of the VEF is on three main categories of learning behaviours that combine individual learning and social interaction: (1) initiation behaviours (performing the activity, spending time watching or engaging in an activity), (2) transition behaviours (repeating the activity, expressing positive emotional responses in reaction to engaging in the activity) and (3) breakthrough behaviours (referring to past experiences while engaging with the activity, seeking and sharing information with others, engaging and involving). The detail applied from Barriault and Pearson's (2010) interpretation of VEF are presented in Table 2.

Table 2: The Visitor Engagement Framework (VEF)

Learning behaviour	Characteristics of learning behaviours
1. Initiation behaviours	
1.1 Performing the activity	• Performing activity in passing, not doing it completely • Performing the activity somewhat completely • Performing the activity without further exploration or testing of variables
1.2 Spending time watching others engaging in activity or observing the exhibit	• Watching the exhibit or watching someone else performing the activity • Watching the exhibit or person using the exhibit with

	expressed interest in the activity (facial expression or verbal) • Expressing interest in learning outcome, learning the activity or doing the activity after observing
2. Transition behaviours	
2.1 Repeating the activity	• Doing the activity two or three times to attain desired outcome. • Enjoying the outcome • Changing the variables to look for a difference in outcome; becoming involved/engaged
2.2 Expressing positive emotional response in reaction to engaging in activity	• Smiling, expressing pleasure with exhibition • Exhibiting stronger signs of enjoyment such as laughter; making verbal references to enjoyment • Expressing obvious signs of eagerness to participate; having an excited disposition
3. Breakthrough behaviours	
3.1 Referring to past experiences while engaging in the activity	• Referencing past experiences with other exhibits or science centres • Making simple references to comparable experiences in life • Making comparisons and deductions based on observations of similarities and differences
3.2 Seeking and sharing information	• Calling someone over to look at exhibit, or to ask them to explain an exhibit; asking a question to staff or family member without lengthy discussion or exploration of topic • Reading signage; having conversations about exhibit and related science with staff or family member • Sharing experience and information with others by explaining the exhibit to them, giving them details about gained information and observations; forming discussions and questions about exhibit with staff or family member/ friend

3.3 Being engaged and involved: testing variables, making comparisons, using information gained from activity	• Engaging in inquisitive behaviour, exploratory actions such as repeating the activity several times, reading signage, asking questions; remaining on task for 2-3 minutes • Exhibiting obvious concentration and motivation; doing the activity as a means to an end or in order to meet a challenge; significant length of interaction, 3 to 5 minutes; treating outcome or result of activity as important • Experimenting, testing different variables, looking for different outcomes; engaging in discussion with others (visitors or staff) about the various outcomes; experiences; staying involved in activity for a long period of time, i.e. more than 5 minutes

Source: Barriault and Pearson's (2010): The Visitor Engagement Framework (VEF).

For this research, using the VEF to investigate learning behaviours is useful in investigating participant interactions, including how they participate or behave to acquire knowledge during the informal learning activities of the Science Caravan. Additionally, the VEF is helpful for investigating participant learning behaviours in relation to the construction of knowledge and outcomes of learning. Furthermore, analysis may also uncover the relationship between contextual learning, learning behaviours and outcomes of learning, including how Thai young people construct knowledge from involvement in the Science Caravan. This is especially pertinent for probing for details on how informal science learning activities meet the needs of different learning behaviours.

3.2 Contexts of learning in informal environments

Falk and Storksdieck's (2005) contextual model of learning has been used as a theoretical construct to investigate factors which affect learning within an informal learning environment. This model draws from constructivism, cognition theory, and sociocultural theories of learning. The model's main feature is its emphasis on frameworks of thinking about learning, which has also been emphasised by others (Falk and Storksdieck, 2005; Chang, 2006; Mortensen and Smart, 2007; Kelly, 2007;

Kanhadilok, 2013). This model is widely applied as a practical framework for research in informal learning situations

Informal education is not limited to museums, as it covers any learning outside of schools such as national parks, aquariums or zoos. This includes programs such as outreach programmes termed as free-choice learning, which play an important role in lifelong education (Falk, 2005; Falk and Storksdieck, 2010). There is a two-step process of learning in a free-choice environment: (1) learners interact with activities or settings to yield a direct experience, and (2) learners assimilate this experience into their existing mental framework to form meaning (Mortensen and Smart, 2007). Hence, education in informal environments is a function of physical environments such as events, activities and informal learning institutes (Falk and Dierking, 2000). As a personal function, learners absorb the current experience to add to existing experiences to make meaning. Influences from society and culture also create meaning for learners as new information is processed through sharing it with others (Falk and Dierking, 2000).

Therefore, the contextual model of learning consists of three main domains: personal, physical and social. The personal domain includes visitor, learners, and participants who engage with informal learning. The physical domain indicates informal learning institutes, events and activities in informal learning settings, and the social domain is characterised by other visitors having an impact on a learner's knowledge acquisition. Educators and practitioners use these domains to identify compliments to learning in informal environments (Mortensen and Smart, 2007). The details are as follows.

(1) Personal context

The personal context originates from constructivist theories of learning, and represents the personal background that an individual learner carries with them into a learning situation. It considers descriptions of prior knowledge influences, museum learning experiences, prior interest or expectations, motivations for participating, and the degree of choice and control over learning (Falk *et al*, 1998; Adelman *et al*, 2000; Falk and Adelman, 2003; Lebeau *et al.*, 2001). Moreover, the link between personal identities such as age, gender, family background, and individual learning has been considered by Chang (2006) and Kelly (2007). Personal context comprises expectations around gaining new knowledge, individual motivation, interest and beliefs, prior knowledge, choice and control, and learner identities.

(2) Physical context

In informal learning, the physical context is the informal learning setting such as the museum or free-choice activities. This covers large-scale properties of venues such as space, lighting and climate. Small-scale considerations include exhibitions, activities and events (Falk and Dierking, 2000; Chang, 2006; Kelly, 2007). Physical context is a relative examination of how learners behave, interact or react during their engagement with informal learning activities. The physical context influences how learners acquire knowledge through observation, interaction and sharing information (Falk and Dierking, 2000).

(3) Sociocultural context

Influences from society and culture are also considered in examining visitor learning in an informal setting. For museums, each visitor's mind set is strongly influenced by the social context. This context draws upon sociocultural theories of learning, which highlight learning with others by sharing, discussing, and communicating. Understanding the social context in informal settings allows us to make sense of the variations in behaviours between groups of visitors. For example, there are visitors who arrive in family, friend, or other participant groups (Falk and Dierking, 1992; 2000; Falk and Storksdieck, 2005).

In this research, the three contexts of the contextual learning model, personal, physical and sociocultural, are designed to underpin the investigation of learning as a result of engaging in the Science Caravan. This model also provides basic knowledge to support the research outline and apply a broader knowledge and understanding of which factors affect learning in informal settings for rural young people.

3.3 Learning outcomes in informal environments

Learning outcomes are products of learning experiences which are used to describe what is retained from involvement in formal or informal learning programmes (Gallavara *et al.*, 2008). In formal learning, learning outcomes are used to make judgements about a learner's progress. Meanwhile, learning outcomes of learning in informal settings are generally used to determine how comprehension relates to factors such as inspiration or enjoyment (Hooper-Greenhill, 2004). Therefore, the investigation of learning outcomes is helpful for this research to determine the relevance of knowledge construction, learning behaviours, and social interactions related to specific informal learning activities.

Participants typically have different reasons for learning in informal environments. They may be focused on using specific archives to research particular content, or they may be casually visiting the site, such as someone visiting an art gallery on their lunch hour or wandering into a library (Parker and Krockover, 2013). In addition, learners have a diverse range of learning styles. As discussed above, they may acquire information by reading, doing, touching, or interacting with others in informal learning environments such as museums, libraries or archives (Falk *et al*., 2008). In formal education such as schools and universities, teachers or lecturers provide content based on the objectives of formal curriculum. In this case learners must follow mapped sequences of learning according to the instruction of the particular learning programme (Kumanyika *et al*., 2010). Informal environments offer learners more freedom as they can control their learning and use more diverse means to obtain knowledge than when learning in formal environments.

Bloom's taxonomy is often used by educators to investigate learning outcomes (Tansey *et al*., 2009). Developed in 1950 to explore the link between external and internal behaviours related to the cognitive development of learners, it is used to classify human learning in classrooms and develop learner-appropriate curriculum. Blooms taxonomy is also used to examine outcomes of learning in informal environments such as zoos, aquariums and museums (Adam, 2015; Bloom, 1956; Krathwohl, Bloom and Bertram, 1973). It includes three domains of learning outcomes: cognitive (knowledge), affective (attitude) and psychomotor (skills) outcomes (Corrallo, 1994). The cognitive learning domain focuses on how behaviours progress from basic demonstration of knowledge up to the ability to evaluate (Krathwohl, Bloom and Bertram, 1973). The affective learning domain focuses on developing emotional skills that allow learners to develop values and attitudes. The psychomotor learning domain includes physical movement which allows for the development of skills and performance from a basic level to mastery (see Figure 2) (Jordan *et al.*, 2008).

Figure 2: Learning domains applied from Bloom's taxonomy

Level			
6	Evaluation		Mastery
5	Synthesis	Generalization	Conscious control
4	Analysis	Value System	Coordinated performance
3	Application	Value	Partial performance
2	Comprehension	Response	Procedural task
1	Knowledge	Attention	Knowledge
	Cognitive (Knowledge)	**Affective (Attitude)**	**Psychomotor (Skills)**

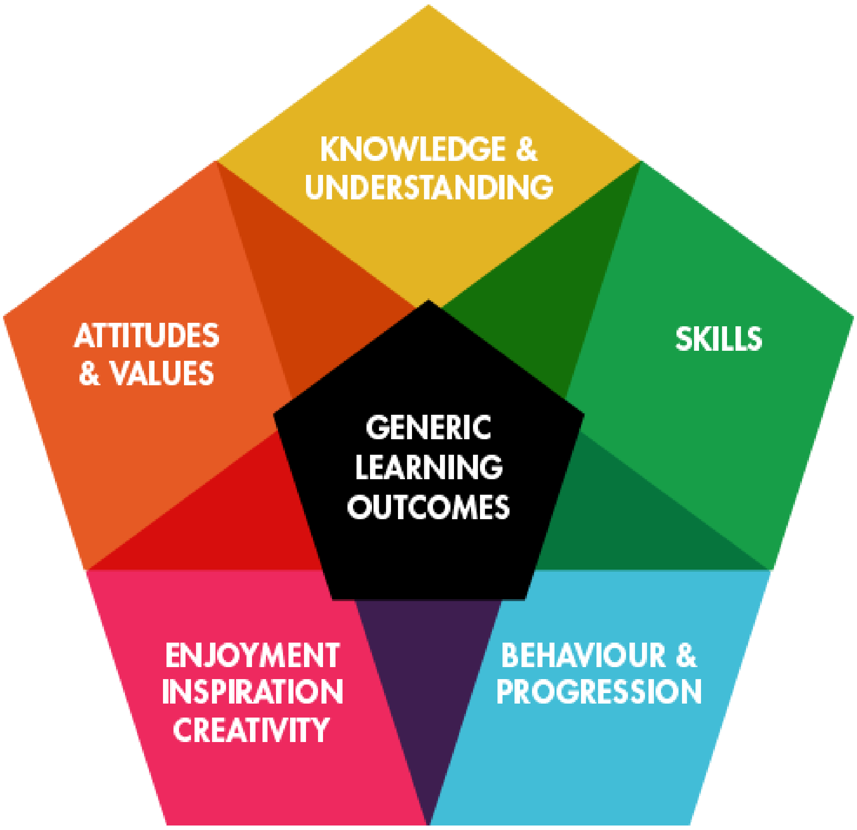
Learning Domains

Note: Applied from (Bloom and Krathwohl, 1956)

In Thailand, informal learning educators have used Bloom's taxonomy to evaluate the learning abilities of Thai students who participate in settings such as zoos, aquariums, science museums and science centres (Pravalpruk, 1999; Chuenjitpongsa, 2009). For example, Punyain (2008) evaluated the learning outcomes of participants at Chiangmai Zoo across three broader constructs based on Bloom's learning domains: science processing skills (skills/psychomotor), scientific thinking (knowledge/cognitive) and attitudes toward science (attitude/affective). However, results from Punyain's research with children in Chiangmai Zoo showed that learning outcomes included more than the three learning domains provided by Bloom, for example, also stimulating creativity and inspiration. Falk (2005) also highlights that other outcomes for learners in informal settings, such as sheer enjoyment may be missed by such categorisations. Therefore, this research considers that there are more than Bloom's three learning outcome domains which are relevant in informal learning.

To address this gap, Hooper-Greenhill (2004) use the generic learning outcomes (GLOs), developed by the UK's Museums, Libraries and Archives Council in 2003, to investigate learning outcomes of visitors to informal learning locations such as museums, libraries and archives (Brown, 2007) (see Figure 3).

Figure 3: Generic Learning Outcomes (GLOs)



Source: With permission, reproduced from the Arts Council England (2017a).

The GLOs offer an intersection between their first three categories, which are (1) knowledge and understanding, (2) skills and (3) attitudes and values, and Bloom's taxonomy three domains (cognitive, psychomotor and affective) (Bloom and Krathwohl, 1956). However, the GLOs consider two additional categories. Category 4, enjoyment, inspiration and creativity, is slightly different from Bloom’s taxonomy. It combines characteristics of the affective domain (enjoyment, inspiration) and the cognitive domain (creativity). Category 5, activity, behaviours and progression, is an additional outcome not included in Bloom’s taxonomy. It is concerned with measuring whether any behavioural change occurs or is intended (Brown, 2007). Table 3 presents the further details of the five categories of the Generic Learning Outcomes (GLOs)

Table 3: The five categories of the Generic Learning Outcomes (GLOs)

Category	Details of Learning Outcome
Knowledge and Understanding	• Knowing about something • Learning facts or information • Making sense of something • Deepening understanding • How museums, libraries and archives operate • Building links and relationships between things
Skills	• Knowing how to do something • Being able to do new things • Intellectual skills • Information management skills • Social skills • Communication skills • Physical skills
Attitudes and Values	• Feelings • Perceptions • Opinions about ourselves (e.g. self-esteem) • Opinions or attitudes towards other people • Increased capacity for tolerance • Empathy • Increased motivation • Attitudes towards an organisation (e.g. a museum, archive or library) • Positive and negative attitudes about an experience
Enjoyment, inspiration, creativity	• Having fun • Being surprised • Having innovative thoughts • Exercising creativity • Exploring, experimenting and creating • Being inspired
Activity, behaviour, progression	• What people do • What people intend to do • What people have done • Reported or observed actions • A change in the way that people manage their lives

Source: with permission, copied the Arts Council England (2017b).

Brown (2006) uses the GLOs to establish a research framework to assess general learning outcomes in evaluating learning experiences from a museum website. The results reiterate broader dimensions of learning outcomes beyond knowledge, skills and attitudes. Hooper-Greenhill (2007) suggest that the GLOs are applicable for studying learning outcomes of broader dimensions in the informal experience, such as knowledge, key skills, learning methods and development of the positive learner identity. Moreover, the GLOs provide a uniform framework for informal learning environments, and they are also useful for planning, delivering and evaluating contemporary formal education.

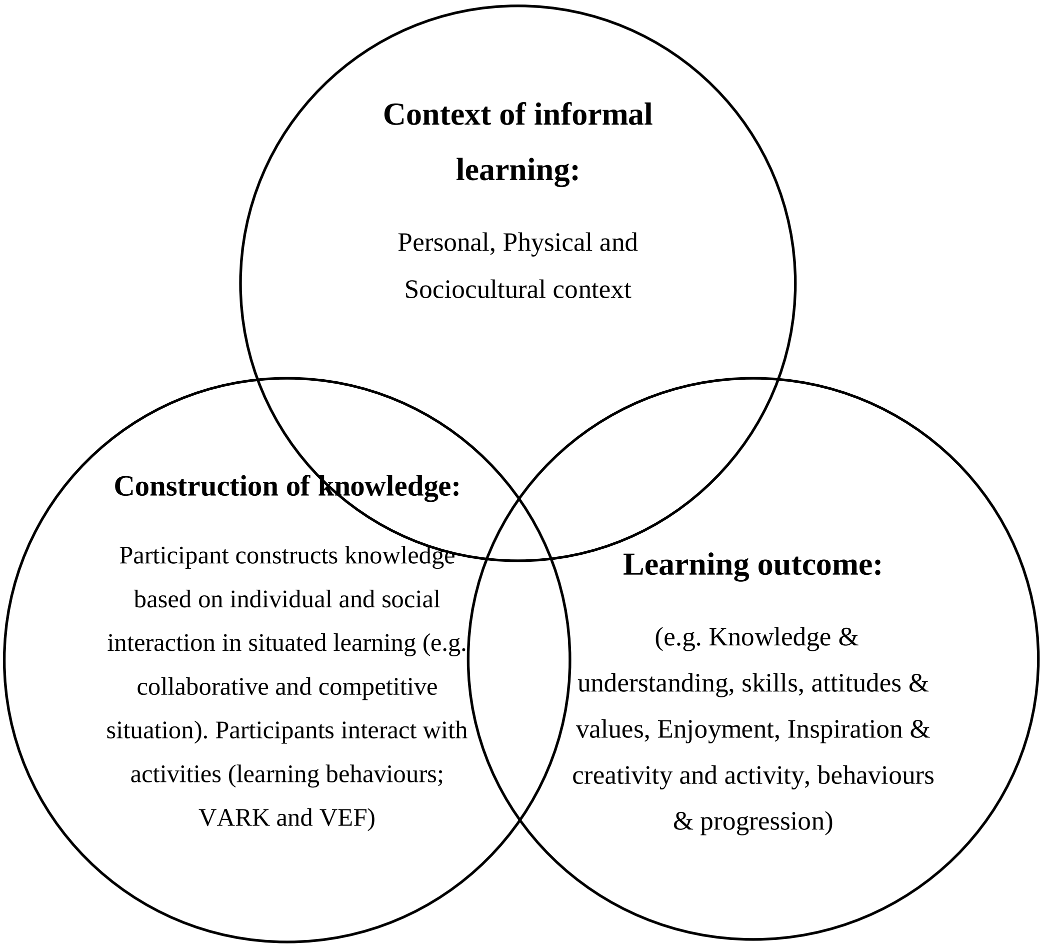
GLO's have also previously been used in informal learning research based in Thailand. Triyarat (2011) applied the GLOs to study the learning outcomes of 30 Thai children (between 7 and 9 years old) participating in a 'Fun Science Room' at the National Science Museum in Thailand. This study found that enjoyment and inspiration were exhibited by most young respondents. This outcome was also linked to further expectations, as the children looked forward to revisiting the room. Moreover, Kanhadilok (2013) used the GLOs to investigate learning outcomes from traditional Thai toys, and finds that enjoyment has an influence on Thai children's ability to learn science.

As the GLOs include broader categories of outcomes than Bloom's taxonomy, using the GLOs for this research may help the researcher gain a better understanding of the learning outcomes of young participants who engage in informal learning activities. Furthermore, this research can be used to compare Western research to broaden knowledge of informal learning in the Thai context.

3.4 The research framework

This research uses the lens of contextual learning perspectives, the construction of knowledge, and learning outcomes to study factors which influence the capacity of participants to learn science in informal environments. Figure 4 presents an overview of the research framework, which was developed using the literature presented in Chapter 2 and the theoretical contexts presented in Chapter 3 in relation to the five research questions. This framework is comprised of three main aspects, as follows.

Figure 4: The Research Framework



(1) Construction of knowledge

Constructivism is used to support the investigation of how rural participants construct their knowledge from their engagement in the informal learning activities of the Science Caravan. As stated in the introduction in Chapter 1, this study examines Thai students who participated in the Science Caravan. In this learning environment, other students, teachers, friends and guides may influence how participants' retain scientific information in this informal setting. Hence, social constructivism is used to investigate the social effects of knowledge construction on participants that link with their individual learning experiences. Additionally, in order to gain a better understanding of the construction of knowledge amongst local young people, Science Caravan participant interactions with informal science activities were investigated in relation to how participants construct their knowledge from informal learning engagements. This thesis also uses the VARK model to investigate individual learning behaviours (visual, audio, reading and kinaesthetic) (Leite et al., 2010; Hawk and Shah, 2007). The VEF developed by Barriault and Pearson (2010) is used to examine local participant interaction with informal science activities. According to this framework, there are three main categories of learning behaviours, which are initiation, transition and breakthrough behaviours. The investigation of knowledge construction partners with learning contexts and outcomes to form a useful outline in considering how to develop informal science learning activities so that they meet the needs of diverse learners.

(2) Contextual learning

As discussed in Section 3.2, Falk and Dierking's (2000) contextual model of learning in informal environments is used in this study to investigate factors which affect the informal learning of local participants in three main contexts: personal, physical and sociocultural contexts. In the personal context, participant demography (gender and age), science knowledge background, informal learning experiences, attitude towards science, personal interests, and expectations are examined. In the physical context, the science activities in the Science Caravan are examined in relation to activities and participant learning in the informal setting. In the sociocultural context, friends, teachers, guides, and other participants from different schools are considered in order to investigate how these people influence participant science learning through involvement in the Science Caravan. This research examines the intersection of these three main contexts in order to determine the factors affecting local young peoples' experiences in informal science learning, resources and settings available to them.

(3) Learning outcomes

In regard to outcomes of learning, the Generic Learning Outcomes (GLOs) are used to investigate what outcomes were gained by participants through engagement in informal science learning activities.

Chapter summary

To build this research framework, this chapter establishes the intersection between the construction of knowledge, learning contexts and learning outcomes in the context of learning in informal environments.

In the construction of knowledge, the relationship between learning theories and learning behaviours are a significant consideration in the investigation of how young people construct their knowledge from informal learning engagements. Social constructivism is used to support the examination of social interactions during participation in informal learning activities in relation to how learners construct knowledge. Cognitive constructivism is used to investigate the construction of new knowledge in relation to prior knowledge and experiences. To address learning behaviours, this research examines learner interactions with informal learning activities by investigating how Thai students engage with the science activities of the Science Caravan and how their interactions relate to their construction of knowledge. This study also explores local participant interactions with activities based on learning behaviours in informal learning outlined by Barriault and Pearson's (2010) framework (initiation, transition and breakthrough behaviours) and VARK model (Leite et al., 2010).

To approach contexts of learning, the contextual learning model by Falk and Dierking (2000) is applied to determine how visitors constructed knowledge from interaction with the activities in the informal learning environment. This study also uses Falk and Dierking's three main contexts, which are personal, physical and sociocultural contexts, as basis for this investigation. This model promotes a better understanding of the relationship between contextual learning and knowledge construction from informal learning engagement in order to investigate factors affecting learning in informal environments.

Learning outcomes in this research are defined as a result of learning from engagement in informal learning activities. Examining learning outcomes is useful for promoting a better understanding of what is gained by student participants from informal science learning activities involvement. As informal learning has different learning processes than formal learning, learners have choices, whereas teachers in formal settings provide stricter learning programmes for students in classrooms. In formal education, the examination of learning outcomes focuses on three categories: knowledge, attitude and skills. Consequently, informal learning includes different ways of retaining new information, and learners can more readily enjoy the learning atmosphere. Therefore, this study's examination of learning outcomes in informal learning focused on the five outcomes it considered useful, using the generic learning outcomes as a guide (Arts Council England, 2017a).

Investigating these three significant components (context of informal learning, the construction of knowledge and learning outcome) has enabled the researcher to construct a research framework that will be used to answer this study's five research questions (Chapter 1, Section 1.3). This theoretical framework is essential in building an effective research design and methodology, and is vital to determine suitable methods for obtaining research results. Chapter 4 presents the research design and methodology of this investigation.

Chapter 4
Methodology

Overview

This chapter presents an outline of the research methodology and design employed in order to address the research questions. The epistemological framework, design of the research, ethical considerations, details of the research setting, sampling strategies, information on the research participants and an outline of the data collection and analysis approach, are presented in this chapter.

4.1 Epistemological framework

The aim of this research was to investigate the impact of the Science Caravan's small-scale activities, 'The Red Route', on Thai young people and the Science Caravan's capacity to meet regional learning needs. Knowledge and understanding of the relationship between informal science learning and science knowledge and skills development provided a foundation to support the researcher's development of an effective research design. Exploration of the relevant literature and theoretical framework proved a useful initial process in the research development in order to increase the accuracy and precision of this investigation (Hart and Open University, 1998). The literature reviewed addressed informal learning development, science knowledge and learning skills development, engagement with informal science learning, the characteristics of underserved participants and learning within informal science activities.

As this research adopted an approach which included constructivist learning theories, the contextual model of learning in informal environments and included an interest in learning outcomes broadly, a mixed methods approach, targeting the views and perceptions from a range of participants was deemed appropriate. This included a deductive approach with the use of a pre and post questionnaire (Robson, 2011; Ritche and Lewis, 2003). As well as inductive techniques with the use of semi-structured interviews (Braun and Clarke, 2013). A convergent parallel design was employed for data collection and analysis. This involves investigating a single topic by two different methods to enhance validation of results (Creswell and Plano Clark, 2011). The interview and the questionnaire approaches used in this research were given equal priority in addressing the research problem. Data collection and analysis were undertaken independently and then mixed or merged during the overall interpretation (Braun and Clarke, 2013) to enable the research questions to be addressed.

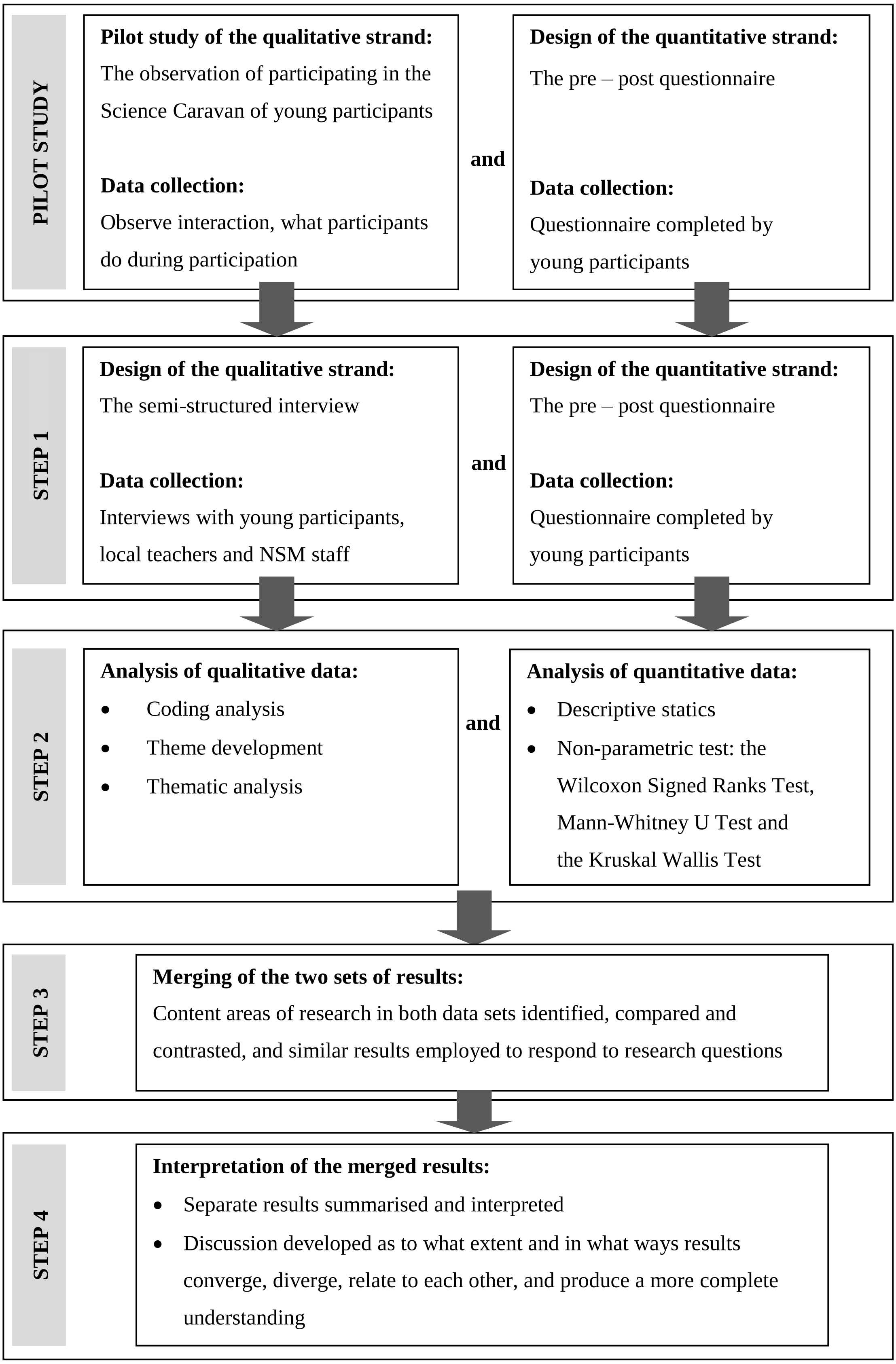
4.2 Research design

In this research, quantitative and qualitative strategies were employed to explore the existing science activities in the Science Caravan and how these activities may support the needs of young people in different regions. The quantitative and qualitative mixed methods approach incorporated a pre questionnaire, a post questionnaire and an interview, respectively. The strength of a quantitative method, such as a questionnaire, derives from the ability to obtain large numbers of participants to generate a better understanding of the broader dimensions of a research context (Creswell and Plano Clark, 2011). Additionally, this method produces larger data sets that can be more easily generalised to other similar situations (Johnson and Christensen, 1941). However, quantitative approaches can lack in-depth investigation, and may not have direct application to specific contexts (Neuman, 2014). Qualitative methods, such as interviews, allow a researcher to investigate multiple perspectives in-depth (Robson, 2011), and can be useful for in-depth study of a small number of participants which helps to elucidate complex phenomena (Bryman, 2012). One major limitation of such an approach is that knowledge gained from small numbers of participants may not be generalizable to other settings (Denscombe, 2007). Using only a qualitative or quantitative method may not therefore have supported the aims and purpose of this research. A mixed methods approach was used for this investigation because each method was able to compensate for the shortcomings of the other (Creswell, 2014), supporting a broader understanding of informal learning in a regional context and leading.

The mixed methods design allowed for convergence of results from different methods (Bryman, 1988 cited by Creswell and Plano Clark, 2011). This provided methodological triangulation through the use of both quantitative and qualitative data collection methods and analysis in exploring the same phenomena (Hussien, 2015).

A convergent parallel design was the type of research design employed (see Figure 5).

Figure 5: Convergent parallel design of the research



The convergent design was initially conceptualized as a ‘triangulation’ design where the two different methods were used to obtain results about the topic (Creswell and Plano Clark, 2011). This research used concurrent timing to implement the quantitative and qualitative strands during the same phase of the process, and both methods were of equal importance. The results of both data collection methods were analysed independently. In the overall interpretation, the results have been combined to develop the researchers’ knowledge and understanding and address the research questions (Creswell and Plano Clark, 2011). The flowchart of the basic procedure in implementing a convergent design of Creswell and Plano Clark (2011) was applied to this research design.

To refine responses to the research questions, the pre – post questionnaire was used to explore the relationship between science activities in the Science Caravan and young peoples’ science learning and was used with students only. The questionnaire process was efficient and easy to complete, even with a large number of participants, when compared with face-to-face interviews (Foddy, 1993) and questionnaire participants can have more independence without any bias in data collection (Bechhofer *et al.*, 2000). Findings from the questionnaire survey also helped inform the development of the qualitative method, as it allowed the researcher to better comprehend and more clearly understand the research context (Bryman, 1988). In this research, the questions in the quantitative questionnaire were based on the three domains of Falk and Direking (2000)’s contextual learning model, with questions eliciting information on individuals personal contexts, the physical context of the Science Caravan environment and the sociocultural context that surrounds them. Additionally, the quantitative questionnaire was also used to explore the relationship between the different learning behaviours and learning outcomes of the young people who engage with science activities in different regions.

This research aimed to incorporate the perspectives of students, local teachers and NSM staff’. The semi-structured interviews were used to investigate participants’ perspectives in these three groups. The semi-structured interview entailed a clear list of issues to be addressed and questions to be answered. This list helps a researcher to keep track of all the questions that need to be asked, so it is a useful strategy to help obtain accurate data from research participants. Additionally, semi-structured interviews permit more flexibility than structured interviews, allowing for the interviewees to develop ideas and elaborate more widely on issues raised by the researcher (Denscombe, 2007).

In this study, five research questions were considered with qualitative and quantitative analysis used to generate knowledge from both data sets. Table 4 presents all of the methods, timings, and analysis, of this research used to respond the research questions.

Table 4: Research Design

Research question	Methods of data collection	Timing and location	Data analysis
1. What setting or resources are available to young people for informal science learning at the regional level? 2. What are the main factors affecting young people's experiences of informal learning? 3. How do informal science learning activities meet the needs of different learning? 4. What learning and other outcomes do young people obtain from participating in regional informal science activities? 5. How can this learning be applied to other informal science communication project at a regional level?	**Quantitative Enquiry:** The pre – post questionnaire completed by young participants. **Qualitative enquiry:** • Young participant interviews • Regional teacher interviews • NSM staff interviews	**Concurrent:** The interview and the questionnaire were collected in the same day and area. The pre – post questionnaire was completed by the interviewees. There were four data collection methods: • Young participant interviews • Regional teacher interviews • NSM staff interviews • The pre – post questionnaire completed by young participants. **Timing and location of data collection:** **The Northeast:** • 12 – 13 June 2014: Nakhonphanom • 16- 17 June 2014: Mahasarakham **The Centre:** • 17 – 18 July 2014: Lopburi • 21 – 22 July 2014: Kanchanaburi **The North:** • 30 June – 1 July 2014: Sukhothai • 3 – 4 July 2014: Phayao **The South:** • 31 July – 1 August 2014: Chumporn • 4 – 5 August 2014: Nakhon Si Thammarat	**Quantitative data set:** The pre – post questionnaire completed by young participants. **Qualitative data sets:** • Young participant interviews • Regional teacher interviews • NSM staff interviews (see Chapter 5 to Chapter 8)

4.3 The Science Caravan

As the aim of this research focused on young people who lack the opportunity to be involved with informal science learning, 'The Science Caravan – Red Route' was seen to be a suitable site for data collection for this research. Research participants were, therefore, the visitors to the Science Caravan – Red Route', which primarily caters for visitors aged from 10 - 15 years old. These participants have limited opportunities for science learning experiences in formal and informal education. They also comprise primarily rural populations, which have lower science performance on national tests, compared to youth in urban areas (see 1.2.6 and 1.2.7 in Chapter 1).

4.3.1 The informal science activities in the Science Caravan

The Science Caravan contains four main science activities as follows:

(1) Science show

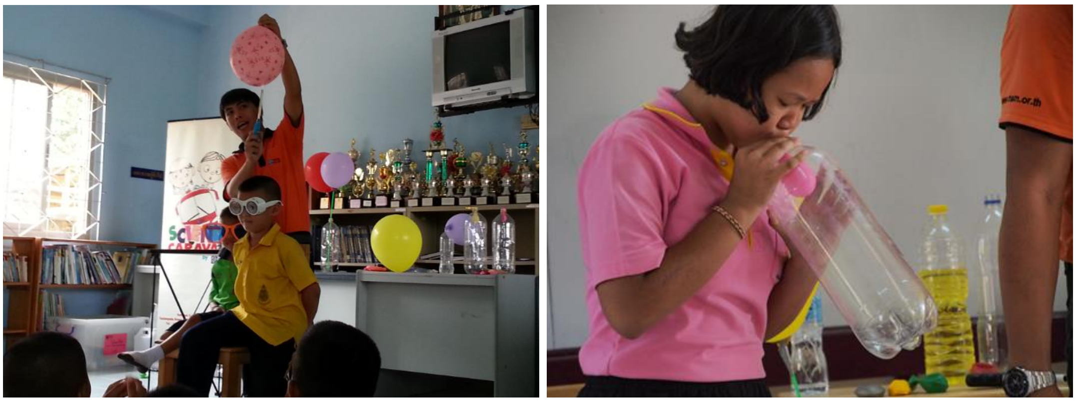
- Aims to stimulate participant interest in science and technology and to support awareness of their importance.
- Scientific phenomena are linked to everyday life to help the audience gain an awareness of its relevance to their own lives.
- Science experiments are presented on stage and intend to excite and amaze the audience.
- Can seat audiences of between 250 to 500 per performance (see Figure 6).

Figure 6: Science show

(2) Science demonstration

- Aims to support the audience's science understanding by linking to the Science Show's content.
- Presented to visitors between the show and their opportunity to participate in science experiments.
- Capacity of the demonstration is lower, with approximately 50 students attending a demonstration class (see Figure 7).

Figure 7: Science demonstration



(3) Science exhibition

- Aims to stimulate participants' development of self-learning skills and science knowledge through hands-on exhibitions.
- Activates self-directed learning by reading instructions on how to use exhibits, and provides scientific information.
- Question sheets help participants reflect on their learning. NSM staff are available to explain and answer all questions on the sheets at the end of activity.
- Exhibitions focus on two areas: the Science of Life Science (Figure 8) and the Science of Materials (Figure 9).

Figure 8: The Science of Life exhibition

Figure 9: The Science of Materials exhibition

(4) Science games

- Aims to promote learning together, sharing and communication, and self-esteem through science games.
- Games, such as Tangram, focus on teamwork skills and mathematical ability, while the Chicken Voice explores the science of sound.
- Designed to encourage participants to practice problem-solving skills based on scientific methods and social skills (see Figure 10).

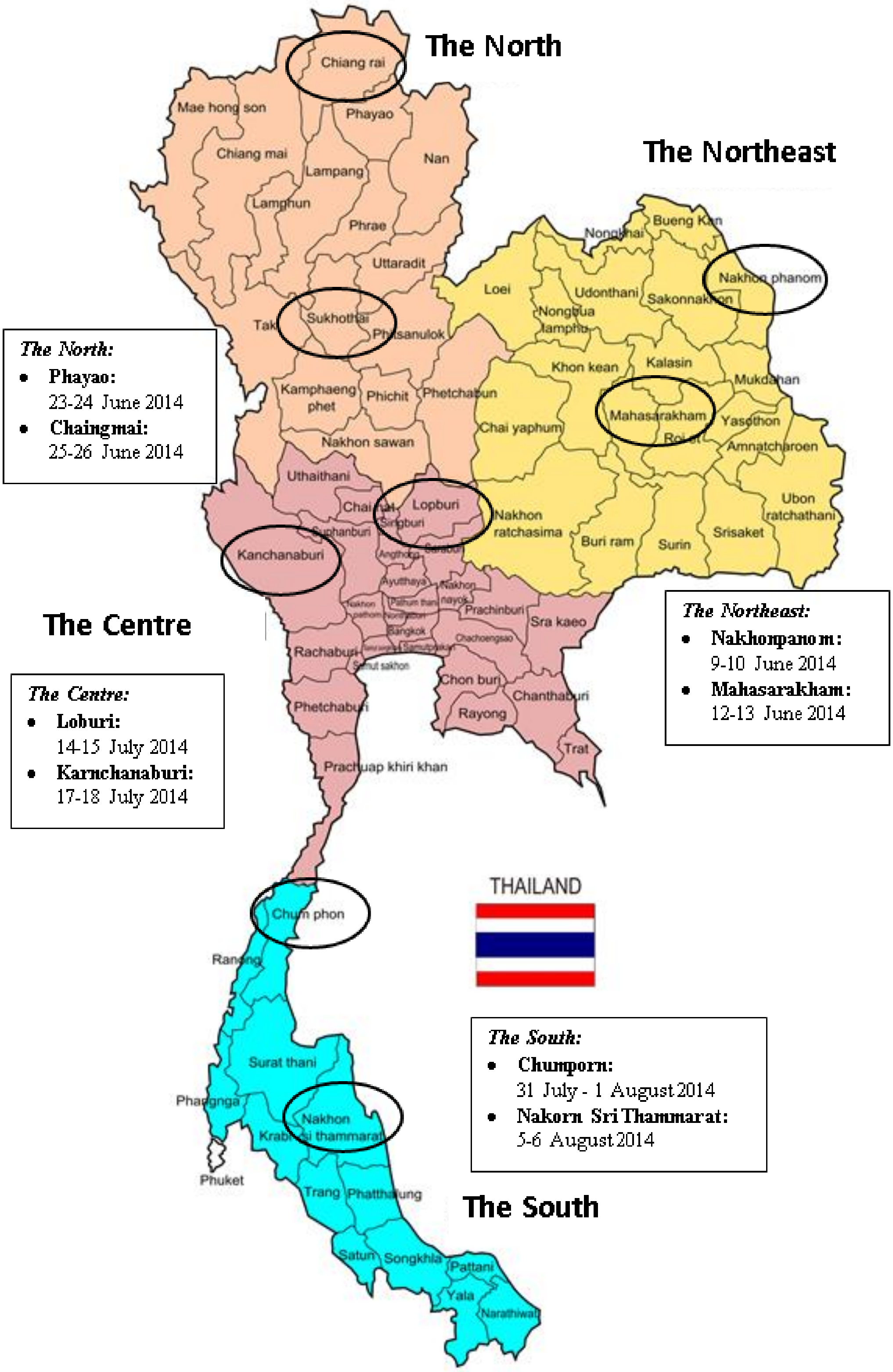
Figure 10: Science games: the Chicken Voice and Tangram

4.3.2 Participants and locations of the Science Caravan

There are two groups of caravan audiences, students from the host school and students from neighbouring schools. As the caravan's maximum capacity for each day is 500 participants, students from host schools were the main participants in the caravan. Students from neighbouring schools are invited by the host school. The neighbouring schools' teachers have to select students based on the quota of participants determined by the host school

Host schools are selected based on three main criteria: firstly, host schools lack of opportunities to participate in science activities outside of the classroom; secondly, they are located at some distance from the main Science Caravan sites; thirdly, the schools were classified as small scale schools based on the database of Thailand's Office of the Basic Education Commission (2011). These schools have less than 120 students and the lowest academic performance according to Thai education standards. On the other hand, these schools have a higher investment in student development, such as having one teacher for 18 students (one teacher for 25 students is the standards for Thailand (OBEC, 2011)). The NSM identifies a pool of possible host schools from the small-scale schools listed in OBEC's database for each region and contacts them for permission for a caravan visit. The distances between school locations is also considered so that the caravan team can travel from one location to the next. The Science Caravan's route is determined for each academic term (three terms a year), where it visits 12 provinces in four regions. In this research, the locations for the data collection were the first two host schools in each of the four regions (eight locations in total) (see Figure 11).

Figure 11: The research setting of this study

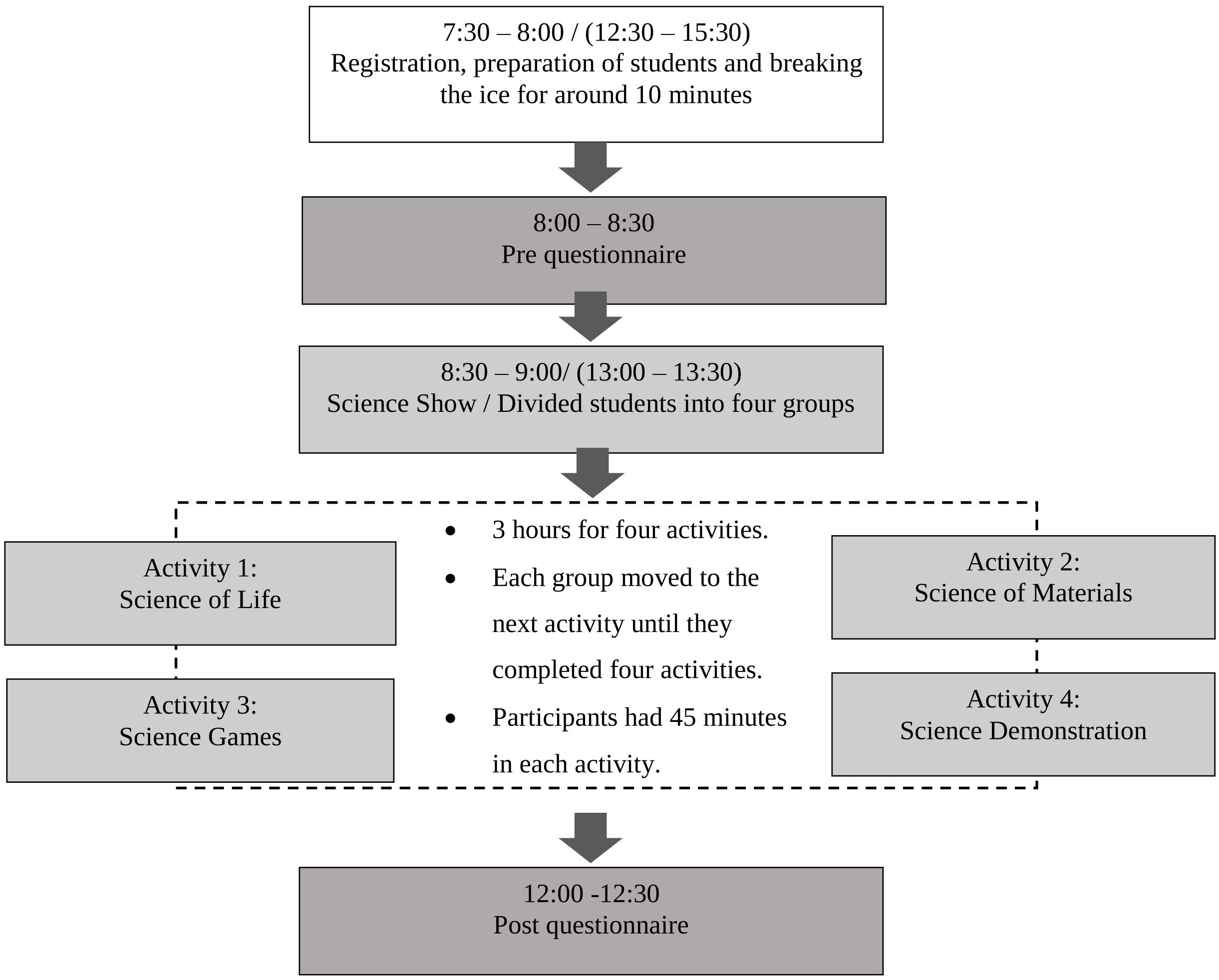


4.3.3 The Science Caravan pattern for conducting science activities

The caravan visits each school for two days and each day has two rounds a day; one in the morning and one in the afternoon, making a total of four rounds. The first round primarily serves students from the host school, and the second, third and the fourth rounds serve students from neighbouring schools.

The pre and post questionnaires were collected from participants in the mornings of the two days. In the afternoons, the morning participants were invited to take part in the interviews (5 teachers and 10 students for each region). The details concerning the Science Caravan's pattern of conducting science activities and quantitative data collection is presented in Figure 12.

Figure 12: Science Caravan programme and quantitative data collection



4.4 Pilot study and research design development

4.4.1 The pilot study

A pilot study can play an essential part in the early stages of the research process, helping to develop and test the research instruments. It can also train researchers in many elements which characterise their particular study, acting as a guide for developing research questions and planning toward the study's purpose (Van Teijlingen and Hundley, 2002). This study employed a pilot study in its early stage in order to examine methods of data collection and analysis and to identify limitations in the initial research design. Additionally, the analysis and results of the pilot questionnaire and observations were used to improve and develop more practical methods of data collection and analysis for this research.

The pilot study for this research was organised in Chaingmai (an area in northern Thailand) from 12 to 15 November, 2013. In this pilot, the pre-post questionnaire and the observation approaches were designed for data collection from participants in the Science Caravan (aged 10 to 15 years old). An observation sheet was also designed to investigate the learning behaviours of participants during interaction with the Science Caravan.

From the pilot study, it was clear that most participants felt uncomfortable in engaging with activities when the researcher observed them directly. Whilst, questionnaire and informal conversation with some participants and their teachers were more favourably received. Therefore, the pre-post questionnaire and the interview approaches were selected for ongoing data collection in this research.

(1) The pre and post questionnaire

A questionnaire was designed to gather broad information on the relationship between visitors and science activities and to gain a better understanding of the learning outcomes, attitude towards science and activities, knowledge background and demography of visitors. For the pilot study, 105 pre- and post- questionnaires were collected from Science Caravan participants. They were selected from seven of 96 schools that were visited in the North. These were four schools from Chaingmai and one school each in Payoa, Nan, and Phrae province. From the seven schools, 15 students each were chosen for the pre- and the post-questionnaire. These 15 participants were selected by random sampling as they queued to participate in the caravan. Participants who had odd numbered seats in the queue were selected. Furthermore, for the pilot study, schools were selected for participation according to the willingness of school directors to participate. In the pilot activity, teachers were key in encouraging student involvement with the Science Caravan engagement and data collection. The study and the role of participants were explained in detail to the teachers, and then the teachers presented an explanation of the questionnaire to their students.

(2) The observation

Observation was also included in the pilot stage. The Science Caravan activities were divided into three groups based on the three main activities; science exhibitions, science experiments and science shows. An observation sheet (see Appendix A.3) was used to record the data, which included observations from photographs and video recordings. The directors of seven schools participating in this research were required to give consent for their students to be photographed and videoed. The consent form and observation sheet were sent to every school, and was attached to the NSM's invitation to attend the caravan. The researcher asked these directors again when they and their students visited the Science Caravan for their permission to involve pupils in the research activities, including observations. The observation was focused on audience interaction with the Science Caravan activities. In terms of the selection of participants to observe, the fifth pupil in each row was chosen during queuing for entrance to the caravan. Observation data were recorded from the moment participants entered the room until they walked out after the activity.

4.4.2 The limitations of the research design identified in piloting

Regarding the pre and post questionnaires, the limited amount of time most of the visitors spent in the Science Caravan was the major problem encountered as it constrained completion of both questionnaires. This meant that open questions requesting visitor comments about participating in the Science Caravan were usually left empty. 98 questionnaires were returned without any answers to the open questions. Additionally, many participants asked questions about certain parts of the questionnaire because the wording of these questions was not clear to them.

For the observations, the size of the activity rooms limited the camera recordings, as it was difficult to set up the video camera to record the entire area. Moreover, most of the students felt uncomfortable interacting with activities knowing that they were being recorded by video and photos taken, though photography turned out to be easier than video. However, the photos were not able to capture the participant's opinions or outcomes associated with that involvement.

From, observation, participants only expressed smiles and remained quiet during their interaction with the caravan activities at the time the researcher observed them, giving little detail in terms of their interactions, feelings and learning during these activities.

4.4.3 The development of the research design

The pilot study suggested that the language used in the questionnaire needed improvement. Participant comments during the pilot studies about the wording of certain parts of the questionnaire were used to improve the clarity of the next round of questions. For example, participants did not understand some questions because of the formal language used. These questions were revised to use more informal language to encourage responses. The structure of the questionnaire was also rearranged based on the purpose of the study, and attention was paid to supporting participant understanding by avoiding jargon and using a simpler structure.

Due to the limitations explored above, the observation method turned out not to be a useful approach to collect in-depth information about how participants engaged with science activities in the caravan. Additionally, open questions on the questionnaire were left blank, making this an unsuitable method to collect more in depth information. For these reasons, interviews were chosen as a method to collect in-depth data. The interviews were designed to cover identical issues originally foreseen for the questionnaire but allow for more in-depth elaboration on the part of participants (see Appendix A.6 to A.8 for details of the interview schedule). Additionally, a small number of interviews with teachers were used to gather information from them on students' backgrounds, the relationships between student background and science learning and attitudes, as well as the impact of the Science Caravan activities on the school environment.

The pilot study was useful as a tool for informing and refining the study. The researcher had the opportunity to talk with young people and teachers about their opinions using the questionnaire questions as a guide. These informal conversations enabled the researcher to gain more detailed information than by observation alone. Therefore, interviews replaced observations for data collection in the final research design. Additionally, the pre and the post questionnaires were refined and developed as the major research method for this study, and photos were taken to support researcher recognition of participant interaction in activities.

4.5 Questionnaire

In this research, pre and post questionnaires were used to collect data in order to observe the participants before and after caravan participation, looking for any changes such as in their knowledge and attitudes. Respondents to the questionnaire were students in Thailand (aged 10-15; 10 – 12 years old for primary school, and 13 – 15 years old for high school) who participated in the small scale version of the Science Caravan.

4.5.1 Design of the pre questionnaire

The pre questionnaire was designed to explore participants' knowledge and attitudes before they participated in Science Caravan activities. The pre-questionnaire covers six areas as follows (see Appendix A.4):

(1) The demographics of participants

This section explored the context of student participants based on the framework of Thai demographics as presented by the National Statistic Office of Thailand (2008). For example, age, gender, religion, and guardian information (in terms of their educational background, occupation, and religion). These questions sought to determine how these components are related to student learning behaviour, attitudes, and outcomes and how these relate to their experiences during the science caravan activities.

(2) Interest and involvement in science

This part of the questionnaire aimed to explore the general interests of students in terms of science, and how they access information about science and technology.

(3) Attitudes toward science

This section was designed to explore participant attitudes toward science to enable comparison with the post-questionnaire with a view to understanding the effect of Science Caravan participation on these attitudes. The questions utilised in this section were adapted from a survey by the National Statistic Office of Thailand (2008) which investigates attitudes toward science.

(4) Science knowledge background

This section aimed to explore the scientific knowledge of students before participation to allow the impact of participation on knowledge to be explored. The questions for this section were adapted from the National Survey of Science Knowledge of Thai People (Thailand National Statistic Office, 2008), and also related to around the content of the science caravan activities.

(5) Science caravan

This part surveyed the students' expectations from Science Caravan participation.

4.5.2 Design of the post questionnaire

The post questionnaire was designed to gather participant reactions after they had participated in science activities. The post questionnaire was organised as follows (see Appendix A.5):

(1) Attitudes toward science and technology

This part surveyed the attitude of visitors towards the science; these were compared with the pre questionnaire to ascertain assess the effects of the Science Caravan activities on participant attitudes.

(2) Science knowledge background

This section explored scientific knowledge and was compared with the results from the pre questionnaire to examine how participation affected visitors' science knowledge.

The pre-test and the post-test questionnaires each asked ten questions on science and technology which were drawn from the National Survey of Science Knowledge of Thai People (the National Statistic Office, Thailand, 2008), and three additional science questions that were directly related to the science activities in the Science

Caravan Project. Thus, the pre- and post-questionnaire had thirteen questions that aimed to investigate any changes in science knowledge arising from participation in the Science. These questions were all closed questions; the participants selected one answer from the three choices “Yes”, “No” or “Don’t know” to reply to each question (see Appendix A.4-A.5: The pre- and the post-questionnaire).

(3) Experience in Science Caravan

This explored the impressions of the science activities students had participated in. The results allowed for analysis of variations in the popularity of specific activities at a regional level. They also allowed for an observation of whether other factors, such as demographic factors, influenced popularity.

(4) Science learning outcomes and perceptions related to science activities

The survey questions in this section were designed to explore both perceptions and outcomes of science learning in order to gain an understanding of the caravan’s effectiveness. The questionnaire asked participants to detail what they had learned from the science activities. Students provided this information in the post questionnaire section on learning outcomes, which features ten questions. The questions were developed from Punyain’s (2008) constructivist learning environment survey, a questionnaire that was used to explore the learning outcomes of visitors to the Chiang Mai Zoo. There are thirty questions in Punyain’s survey that relate to the learning context of Thai children in informal settings, and they are located under the ‘Knowledge and Understanding’ and ‘Skills and Attitudes’ sections. To incorporate the informal environmental context, the Generic Learning Outcomes (GLOs) were also used to frame the questions based on five learning categories. The categories included Knowledge and Understanding; Skills; Attitudes and Values; Inspiration, Creativity and Enjoyment; and Activity, Behaviour and Progression (Hooper-Greenhill, 2004) (see Table 5). The ten questions were tailored for this research, seeking to discover both what was learned and any differences in learning outcomes between regions.

Table 5: Learning outcomes and perceptions of learning science through science activities (post-questionnaire), linked with the categories of learning outcomes from the GLOs.

Questions	The categories of learning outcome of the GLOs.
1. I discovered something I didn't know about science and technology from the science activities in the Science Caravan.	**Knowledge and Understanding:** Learning what about something new, making sense of something **Inspiration, Creativity, Enjoyment:** Being surprised
2. I don't want to be involved with science activities.	**Attitudes and Values:** Feelings, negative and positive attitudes toward activities, involvement
3. I talked with friends about solving the problem.	**Skills:** Communication skills, social skills
4. I didn't read the instructions for activities from a panel or a manual.	**Skills:** Learning skills, reading skills, physical skills, social skills
5. It was okay for me to express my opinion.	**Attitudes and Values:** Opinion about themselves (self-esteem in terms of confidence)
6. I found that using scientific methods to find the answer was difficult for me.	**Attitudes and Values:** Feelings, difficulty, negative feelings toward dealing with problem, obstacle to involvement with this event **Skills:** Knowing how to do something, solving problem
7. I learned that science cannot provide perfect answers to problems.	**Inspiration, Creativity, Enjoyment:** Science can help them answer many questions, experiment, think about the hypothesis, create ways to solve problems **Attitudes and Values:** Negative feelings about the limitation of science
8. The science activities made me enjoy science more.	**Inspiration, Creativity, Enjoyment:** Having fun
9. I think I will use some knowledge that I obtained from science activities to improve my studies in science class.	**Activity, Behaviour and Progression:** What they intend to do later
10. I will tell my family and my friends about the importance of science and technology after my caravan visit.	**Activity, Behaviour and Progression:** What they intend to do later

4.5.3 Research participants and recruitment

In this research, the sample size was determined by comparing the total number of participants to the sample required to produce results that are accurate to + 5% with 95% confidence (Krejcie and Morgan, 1970; Gomm, 2008). From the data recorded on Science Caravan participants in 2013, the total number of participants is approximately 12,000 participants from four regions, and the total number of participants in each region is approximately 3,000. Accordingly to achieve an acceptable sample size for this study based on Krejcie and Morgan (1970), the sample from each region should be 341. Thus, a sample size of 350 was sought for each region to allow for missing or unusable responses. Every student who participated in a morning session was asked to complete the pre- and the post-questionnaire so that the caravan team could begin activities for all participants at the same time. After completing the caravan activities, all participants were asked to complete the post questionnaire at the same time. Matched questionnaire responses were selected from the pool of completed questionnaires through a process of randomisation: the researcher assigned an order number labelled on the pre- and the post-questionnaires. Then, 350 responses were selected by picking out the odd order numbers from the forms. Questionnaires were checked to ensure that data were collected from a similar number of females and males.

4.5.4 Quantitative data analysis

Descriptive statistics were used to investigate the general features of the quantitative data. Results from descriptive analysis provided simple summaries about the sample which the researcher can use to gain an overview of the trends in the results. This summary information helped the researcher to make a precise decision on which issues to examine further (Healey, 2009). Examples of this include frequency of data in terms of demographic backgrounds, informal learning settings available to young people, and the most and the least popular science activities (see Chapter 5 to Chapter 8).

For comparison of results between pre- and post-questionnaire responses taken from the same individual, the Wilcoxon signed-rank test was used to identify the changes in attitudes towards science and science knowledge. A t-test cannot be used on these data to investigate differences between the pre- and post-questionnaire results because the sample size is too small. Moreover, the data were ordinary and nominal, so it is inappropriate to use parametric statistical tests, such as a T-test. Therefore, nonparametric statistical tests like the Wilcoxon signed-rank test are appropriate for this analysis (Corder and Foreman, 2014).

To compare regional differences (the Northeast, the North, the Centre and the South) in the pre- post-questionnaire the Kruskal-Wallis test was used. The Mann-Whitney U test was used to test for differences between male and female participants, and between age groups (10-12 years old and 13-15 years old) (Hinton *et al.,* 2014). The Kruskal-Wallis test and the Mann-Whitney U test are nonparametric statistical tests. These tests can be used to investigate independent data: if there are more than two independent groups, The Kruskal-Wallis test is used, and if there are only two independent groups, the Mann-Whitney U test is used. These tests were used to examine the changing of science knowledge background, attitude towards science and learning outcomes of different groups of participants (Field, 2009). SPSS computer software was used for statistical analysis of quantitative data as it was deemed most appropriate to compare the pre- and post-questionnaires using the statistical tests outlined above (Hinton *et al.,* 2014).

4.6 Qualitative enquiry

The semi-structured nature of the interviews allowed the interview process to be natural and encouraged interviewees to present their ideas independently. This research used semi-structured interviews for three respondent groups: NSM staff, student participants (aged 10-15), and teachers. A list of questions was used for the interviews which was tailored for each group and designed to cover the topics relevant to this research. The interviewees were asked the questions with some flexibility to respond to the points in differing order based on semi-structured interview techniques (Bryman, 2012). A benefit of this method is that it allowed interviewees to feel a sense of openness in answering the questions (Burn, 2004) and raised unanticipated issues which were relevant to each respondent’s particular position.

The interview data provide in-depth detail about the relationship between science and technology and the local population in terms of people’s attitudes towards science and technology and learning and teaching science and technology in schools.

Additionally, significant resources and factors affecting students learning in informal science settings were explored in the interviews. Learning behaviours of participants as they interacted with activities in the caravan were investigated. In addition, other learning outcomes from involvement in the Science Caravan were also explored.

4.6.1 Semi-structured interview design

(1) The student interview

This interview was designed to investigate how the participants engaged with science activities, and it explored their perspectives on learning science beyond the classroom. Questions investigated components such as participant perceptions of the Science Caravan, other science activities, and impacts on their attitudes towards science. The results supported an understanding of Thai student interactions with these activities and the impact of the activities on their attitudes towards science. The interviews with the students took place in an informal environment, which encouraged them to present their opinions and experiences in more depth than could be achieved through the questionnaires (see Appendix 6).

(2) The teacher's interview

This interview was designed to explore local student learning styles and behaviours from the teacher's perspective, including how the Science Caravan had affected their students' interests in science. The interview was also used to explore the opportunities available to their students for participation in informal science learning (such as the Science Caravan), including access to science and technology information and informal learning opportunities in each region. These interviews were also used to investigate teacher perceptions of the importance of science to their pupils' likely careers. The results provide an understanding of opportunities available to students in Thailand to learn science outside the classroom, to access science information and activities, and to assess the importance of these opportunities towards future careers (see Appendix A.7).

(3) The NSM staff interview

This interview was designed to explore how the visitors engaged with Science Caravan activities from the perspective of the NSM staff who had the responsibility of developing and facilitating the activities. These interviews aimed to support the other results in cultivating more comprehensive answers regarding the study's research questions through reflections on the NSM staff's experiences with student participants and teachers in the Science Caravan (see Appendix A.8).

4.6.2 Interview research participants and recruitment

(1) Local student participants

Students (aged between 10 and 15 years old) who participated in the small scale Science Caravan were the research pool from which the sample was drawn. Ritchie and Lewis (2003) suggested that the number of participants for individual interviews should be less than 50 people. For this study, 40 young visitors were selected for interviews from the four regions (10 visitors per region). The sample was randomly chosen. In each region, the first and the second trip location were chosen for data collection (see section 4.3.2). Students were selected for interview on the first day of the caravan. Five interviewees were selected from the host school based on the seating position the participants while waiting for the caravan in the morning (see Figure 13). The first person of the first, second, third, fourth and fifth row were selected for interview. However, these interviewees were also considered to ensure that they also represented different ages and genders. In some cases, this meant that the researcher needed to select a different pupil in that row to ensure a wide range of pupil ages were included and to ensure gender diversity in the sample.

Figure 13: Student Interview Selection.

Students mainly represented the host school in the interview sample because of the limited time available to access pupils from other schools. The majority of students from other schools need to return to their school after they had finished all the activities without allowing time for an in depth interview. Each interview lasted from 10 to 15 minutes.

(2) Teachers

Teachers who participated in the Science Caravan with their students were considered for interviews, and interviewees were drawn from each of the four regions. Teachers chosen had been responsible for providing their students access to the science activities, and they were involved in the activities of the caravan to observe and support their students' learning. They were either science teachers or had science teaching experience, and came from both host and visiting schools. The sample included five teachers from each region. Teachers were selected from different schools, with a limit on one teacher participating from any given school. The first five teachers who agreed to participate in the interview were enrolled in the study. Each interview lasted from 25 to 30 minutes, after the teachers had observed their students participating in the caravan activities.

(3) NSM Staff

There were four groups of staff members considered for interviews. The first group included the two project managers, their responsibilities included managing and developing the entire Science Caravan project. The second group contained seven main staff members in the Science Caravan division. The responsibility of this group was to arrange and manage the program at the regional level, and they also developed science games to support the children's learning in the exhibits. The third group included six developers of science activities from the science show and the science experiment teams who supported these activities. The last group contained seven Science Caravan staff members. Hence, 22 staff members were interviewed. Each interview lasted from 25 to 30 minutes, and staff were interviewed separately at the end of their day of conducting caravan activities.

4.6.3 Qualitative data analysis

The interview results were analysed via a thematic analysis used to identify themes and patterns in the data related to the research questions. This method is widely used for analysing qualitative data (Braun and Clarke, 2006). In this research, inductive thematic analysis (TA) was used to capture any themes within the interview results. Inductive TA aims to generate analysis from the data bottom up, and it is useful in shaping standpoints, disciplinary knowledge and researcher epistemology (Braun and Clarke, 2013).

The interview data were coded by applying the thematic analysis coding method based on Braun and Clarke (2013). There were seven processes within this qualitative analysis, beginning with data transcription, reading and familiarisation by taking note of items of potential interest, and using these notes for coding across the entire dataset. Next, a search was performed for themes, and they were reviewed by producing a map of provisional themes, subthemes, and the relationships between them. Next, themes were defined and named to finalise the analysis.

For effective data analysis, NVivo was used to support the thematic coding analysis in this study (Bazeley and Jackson, 2013).

4.7 Ethical issues

Ethics is at the heart of research from the earliest design stages to reporting and beyond. The main principles of effective ethical practice are equity in all investigation processes in the research such as research methodology that starts from how to collect the data through analysis without any bias. Additionally, a key ethical principle considers whether the research is worthwhile, and should not make unreasonable demands on participants (Robson, 2011). Participation in research was based on the principle of informed consent, was voluntary and free from coercion or pressure. Adverse consequences of participation were avoided, and risks of harm stated for participants. Finally, confidentiality and anonymity were respected in order to protect participants, especially young people, from any risk of danger (Bryman, 2012).

Prior to its execution, this research was scrutinised and approved by the Faculty Research Ethics Committee of the University of the West of England, Bristol. In this research, the main research participants were young people aged from 10 to 15 years old. Providing consideration and protection during research activities involving young participants is a significant ethical principle. Potential issues were considered based on the University Research Ethics Committee’s requirements.

After receiving ethics approval and prior to the data collection, the researcher sent via post and email the information sheets and the consent form (see Appendix B) to the NSM staff and the directors of schools. This was in order to ask for permission for data collection. The information sheet stated the aims of the research and the purpose of the data collection. The consent form was provided for the directors of schools to give their permission for the participants to take part in the research activities. The director of each school involved (i.e., the head of each school) considered their students' involvement in research activities. They provided consent to allow their students to take part in the pre – post questionnaires and the interviews. In the interviews, the researcher also explained the research and provided another consent form to allow the young people to consent themselves to partake in the interview.

In the interviews with teachers and NSM staff, the research participants were local teachers who had visited the Science Caravan and NSM staff who had worked in the Science Caravan team. These participants were asked via email or in person to take part in the research interview. The researcher gave potential participants the information sheet and explained the aims of the research and the purpose of the interviews before asking individuals to agree to participate in an interview. The interviewees signed and returned the form to the researcher before the interviews took place. In the interview, the interview questions were designed to be clear and easy to understand. All interviewees were reminded that their answers would be recorded by the Dictaphone, and that they could stop the interview at any time.

There were some additional ethical considerations in regards to this project and the researchers' role within it. Regarding the NSM staff interviews, they may have felt under pressure to participate or been concerned about saying anything critical. As for students and teachers, they may feel reluctant to express their opinion of the Science Caravan as they could believe that the researcher is a member of the caravan staff. As a result, students might find it difficult to state any flaws founded in the caravan, whilst teachers may additionally have found it difficult to discuss limitations of their school relating to science learning. Therefore additional time was provided around interviews to reassure those involved of confidentiality and to encourage them to be honest in their responses. A pseudonym and a code system were used for organising the data files and data storage. The participants were reassured that therefore they could not be identified through their answers. A data code was provided for the data withdrawal of participants.

In the case of the questionnaire data which were collected in hard copy, the pre and the post questionnaires were scanned to provide digital files for secure storage, with the paper based version kept in a lockable filing cabinet. In the interviews, as noted, the Dictaphone was used to record the interviewees' responses. After each recording, the audio files from the Dictaphone were transferred to the computer provided for data storage. The original files were deleted from the recording machines to keep data located only in a secure place with a password-protection system. All computer files such as audio, photos, videos, transcripts and the questionnaires were stored on the university's server and a password protected personal computer.

Chapter summary

In summary, this chapter has identified each method utilised within this research. Mixed methods were chosen to meet the research questions. There are two main methods that were used for this investigation: the pre and the post questionnaires and the semi-structured interviews. The pre and the post questionnaires were designed to consider the relationship between young people and informal science activities, including investigating the relationship between participants' background related to changing attitudes towards science, and how informal science activities promote science learning of research participants, including exploring outcomes of participating in the Science Caravan.

For the interviews, semi-structure interview schedules were designed to collect data from three groups; teachers, students and NSM staff more in-depth. These interviews were designed to investigate how the participants engaged with science activities, explore their perspectives on learning science beyond the classroom, and examine learning styles and behaviours of young participants. Additionally, these interviews were also used to investigate informal science learning opportunities available to participants.

For the quantitative data analysis using SPSS, non-parametric statistics were used; the Wilcoxon signed-rank test was used to compare the pre and the post questionnaire responses, the Mann-Whitney U Test was used to examine the different between two independent variables, and the Kruskal-Wallis test was used to investigate the difference between more than two independent variables. For interview data, the thematic analysis using Nvivo was designed to capture any themes emerging from the interviews.

This research received ethical approval by the Faculty of Health and Applied Sciences Research Ethics Communities. Chapter 5 to Chapter 8 will now consider the result of these data in depth.

Chapter 5
Participant Information and
Informal Science Learning Resources

Overview

This chapter examines quantitative and qualitative results in response to the research question: '*What settings or resources are available to young people for informal science learning at the regional level?'* To respond to this question, informal learning resources that facilitate science learning among young people were examined. Additionally, how these informal learning resources affected participants' science learning experiences was also investigated.

In this chapter, the results are divided into five main sections. In the first part, the participant demographics are presented including age, gender and religion. The data were analysed in relation to their experiences in accessing informal science learning resources and the types of informal learning resources which have the most influence on them. Moreover, participant demographics were also analysed to assess their relationship with science learning, attitudes towards science, scientific knowledge, and experiences from Science Caravan participation. These are explored further in Chapters 6, 7 and 8. In the next part, access to informal science learning is investigated through the pre-questionnaire, whilst the third part draws in data from interviews with participants to find out more about the resources, settings and events of informal science learning young people access. This chapter goes on to discuss how these resources could affect informal science learning experiences. The chapter also reports on participants' and teachers' prior knowledge and expectations of the Science Caravan.

5.1 Participant demographics

5.1.1 Questionnaire characteristics

This section presents the results from the demographic section of the pre-questionnaire (see Appendix A.4). The data came from 1,400 participants from four Thai regions, with each region including 350 students within the sample.

(1) Participant age, gender and religion

- **Age**

Participants were divided into two groups: 10-12 years old (primary school students) and 13-15 years old (high school students). Among those who participated, 65.9% (N =992) were primary school students, whereas 34.1% (N =478) were high school students. In each region, there were more participants between the ages of 10 and 12 than there were between the ages of 13 and 15 (N=1,400) (see Table 6). In the Central region there were slightly larger numbers of respondents who were primary school students, whilst in the South there was the most even distribution of completion amongst primary and high school students.

- **Gender**

A similar number of male and female students were involved in this research project, as evidenced by Table 6. 49.8% (N=697) of respondents were male, whereas 50.2% (N=703) of total participants (N=1,400) were female. The representation of gender was representative of the number of female and male students from each participating school, as there were similar numbers of each gender at schools visited.

Table 6: Participant demographics (age, gender and religion)

	Number of participants (N)				
	The Northeast (N=350)	**The North (N=350)**	**The Centre (N=350)**	**The South (N=350)**	**Total (N=1400)**
Age					
10-12 years old (primary school students)	70.9% (N=248)	61.1% (N=214)	79.4% (N=278)	52.0% (N=182)	65.9% (N=992)
13-15 years old (high school students)	29.1% (N=102)	38.9% (N=136)	20.6% (N=72)	48.0% (N=168)	34.1% (N=478)
Gender					
Male	50.0% (N=175)	48.6% (N=170)	51.4% (N=180)	49.1% (N=172)	49.8% (N=697)
Female	50.0% (N=175)	51.4% (N=180)	48.6% (N=170)	50.9% (N=178)	50.2% (N=703)
Religion					
Buddhism	98.9% (N=346)	100.0% (N=350)	98.6% (N=345)	99.7% (N=349)	99.3% (N=1,390)
Christian	1.1% (N=4)	-	1.1% (N=4)	0.3% (N=1)	0.6% (N=9)
Islam	-	-	0.3% (N=1)	-	0.1% (N=1)

- **Religion**

The majority of participants in the study were of the Buddhist religion. According to Table 6, out of 1,400 participants, 99.3% (N=1,390) were Buddhist, whereas 0.6% (N=9) were Christian and 0.1% (N=1) were Muslim. Buddhists made up more than 98% of participants from each region. From the Centre, the results illustrated that the three religions of Buddhism, Christianity and Islam were present among the respondents. More than 98.6% were Buddhist, 1.1% were Christians, and 0.3% represented Islam. Participants of Buddhist and Christian faiths were present in the South and the Northeast. The main religion represented from both regions was Buddhism, at 98.9% and 99.7% in the Northeast and South. Christians made up 0.3% from the South and 1.1% from the Northeast. From the North, all respondents were Buddhists.

(2) Participant parents and caregivers

The current parent or caregiver of each young participant was recorded. In addition, the background of these parents or caregivers were also evaluated, including occupation, education and religion.

- **Current parent/caregiver**

Information regarding parents or guardians of respondents came from the demographic section of the pre-questionnaire, in which participants were asked a series of questions about the parent or guardian they lived with and who supported their education. As displayed in Table 7, most respondents lived with their father and mother, at 73.4% (N=1,027) of total participants (N=1,400), followed by their mother 11.1% (N=155). 10.6% (N=148) of total respondents indicated living with another caregiver. According to answers to question 4 in the pre questionnaire (see Appendix A.4), 3.9% (N=55) mentioned living with a grandparent, 1.6% (N=23) with an aunt, 0.9% (N=12) with an uncle, 0.1% (N=2) with a sister, and 4.0% (N=56) did not specify the caregiver.

Table 7: Parent or caregiver background

	Number of parents (N)				
	The Northeast (N=350)	The North (N=350)	The Centre (N=350)	The South (N=350)	Total (N=1400)
Current parent/caregiver					
Father and mother	79.7% (N=279)	72.9% (N=255)	66.3% (N=232)	74.6% (N=261)	73.4% (N=1,027)
Father	5.1% (N=18)	3.4% (N=12)	5.4% (N=19)	6.0% (N=21)	5.0% (N=70)
Mother	10.1% (N=35)	7.1% (N=25)	15.7% (N=55)	11.4% (N=40)	11.1% (N=155)
Other caregiver	5.1% (N=18)	16.6% (N=58)	12.6% (N=44)	8.0% (N=28)	10.5% (N=148)

- **Parent and caregiver occupations**

The occupation of parents and caregivers was considered to explore parent and caregiver backgrounds. The results were derived from the responses to pre-questionnaire questions 5, 7 and 9 (see Appendix A.4). The majority of parents were in the two occupational groups of farming/agriculture and temporary staff. As seen in Table 8, over a third of fathers, mothers and caregivers worked in the farming and agricultural sectors as agriculturists, at 36.7% (N=514) (see Table 8).

Table 8: Parent and caregiver occupations

	Number of parent (N)				
	The Northeast (N=350)	The North (N=350)	The Centre (N=350)	The South (N=350)	Total (N=1400)
Parent/caregiver occupations (the most responses)					
Father's occupation	Agriculturist: 38.6% (N=135)	Agriculturist: 49.7% (N=174)	Temporary Staff: 41.1% (N= 144)	Agriculturist: 38.0% (N=133)	Agriculturist: 36.7% (N=514)
Mother's occupation	Agriculturist: 40.9% (N=143)	Agriculturist: 49.4% (N=173)	Temporary Staff: 48.0% (N=168)	Agriculturist: 40.6% (N=142)	Agriculturist: 39.2% (N=549)
Caregiver's occupation	Agriculturist: 3.4% (N=12)	Agriculturist: 10.9% (N=38)	Temporary Staff: 6.6% (N=23)	Agriculturist: 4.0% (N=14)	Agriculturist: 5.5% (N=77)

From the South, Northeast and North, most fathers, mothers and caregivers worked in the agricultural sector. In the Centre, however, it was more commonly the case that fathers (41.1%, N=144) and mothers were temporary staff, at 48% (N=168) (see Table 8).

These results are linked to the economic and geographic characteristics of Thailand. The Centre is an established industrial and business area. Thus, much of its population moved from the agricultural to the industrial sector. Most available jobs in the area are for temporary staff, and they are designed for those with less than a bachelor's degree, which describes a large portion of the Thai population.

- **Parent and caregiver education**

Results from the data demonstrated that parent and caregiver education was mainly below a bachelor's degree. As displayed in Table 9, fathers with less than a bachelor's degree represented 57.2% (N=801) of the population, with the results for mothers' education being similar with 64.7% of mothers having education lower than bachelor's degrees (see Table 9).

Table 9: Parent and caregiver education

	Number of parents (N)				
	The Northeast (N=350)	**The North (N=350)**	**The Centre (N=350)**	**The South (N=350)**	**Total (N=1400)**
Parent/ caregiver education (the most responses)					
Father's education: below bachelor's degree	49.4% (N=173)	58.9% (N=206)	51.7% (N=181)	68.9% (N=241)	57.2% (N=801)
Mother's education: below bachelor's degree	57.4% (N=201)	62.0% (N=217)	62.3% (N=218)	77.1% (N=270)	64.7% (N=906)
Caregiver's education: below bachelor's degree	3.7% (N=13)	12.6% (N=44)	9.4% (N=33)	6.9% (N=24)	8.1% (N=114)

5.1.2 Interview characteristics

In this research, semi-structured interviews were used to collect data from three groups of interviewees. Interviewees included 40 students (10 from each of the four regions), 20 teachers (5 from each of the four regions), and 22 NSM staff who work with the Science Caravan project.

Of the 40 students, there were 17 males and 23 females, and there were 20 host school students and 20 guest school students. 19 of the student interviewees were primary school students and 21 were high school students. The 40 students were further divided into four groups according to their regions of origin: the Northeast, the North, the Centre and the South, and each group had 10 participants. Further details on the participants are included in Table 10.

Table 10: Student interviewee characteristics

Region	Number of participants (N)	Gender		Host - Guest school students		Level of education	
		Male	Female	Host school	Guest school	Primary school	High school
The Northeast	10	4	6	5	5	7	3
The North	10	1	9	5	5	3	7
The Centre	10	6	4	5	5	6	4
The South	10	6	4	5	5	3	7
Total	40	17	23	20	20	19	21

Among the 20 teacher participants, there were 8 males and 12 females, 15 science teachers and 5 non-science teachers, and 12 host school and 8 guest school teachers. There were 5 interviewees from each region (see Table 11).

Table 11: Teacher interviewee characteristics

Region	Number of participants (N)	Gender		Host or Guest school students		Subject	
		Male	Female	Host school	Guest school	Science teacher	Non-science teacher
The Northeast	5	1	4	3	2	4	1
The North	5	2	3	3	2	3	2
The Centre	5	3	2	3	2	4	1
The South	5	2	3	3	2	4	1
Total	20	8	12	12	8	15	5

Among the NSM staff participants, the interviewees were mostly science communicators (N=20), and two directors were interviewed, this included 10 female staff and 12 male staff.

5.2 Questionnaire results: accessing informal science learning resources

This section presents the resources and settings offering informal learning to promote young people's science learning. The results derive from the participants' responses to the pre-questionnaire in the section on interest and involvement in science. These results reveal the informal learning resources and settings, including access to information on science and technology, that participants reported using.

In this study, the pre-questionnaire on informal learning settings and resources was adapted from a survey of 14–16 year olds in the UK on attitudes towards science (Department for Business, Innovation & Skills, 2011). The pre-questionnaire also incorporated knowledge of the informal learning resources available in Thailand (this information was gathered from the pilot questionnaire and from informal interviews with teachers who participated in the Science Caravan project in November 2013 at Maejo University, Chiang Mai, Thailand). The results are presented first in terms of the overall responses from all participants and then in terms of three relevant factors, namely region, age and gender.

5.2.1 All participants

The pre-questionnaire results of all respondents identify the top three informal learning resources as the public library, the zoo and the natural park (see Figure 14). The first setting, the public library, was the key informal learning setting for participants obtaining scientific knowledge outside school; this setting obtained the highest number of responses at 23.8% (N=333). The public library provides science books and free Wi-Fi as well as a computer to support participants' and local people's access to scientific knowledge.

> There are a lot of science books, and I can use a computer to search about scientific knowledge for doing my homework.
> (Sirikanya, a female primary school student, a guest school, the North)

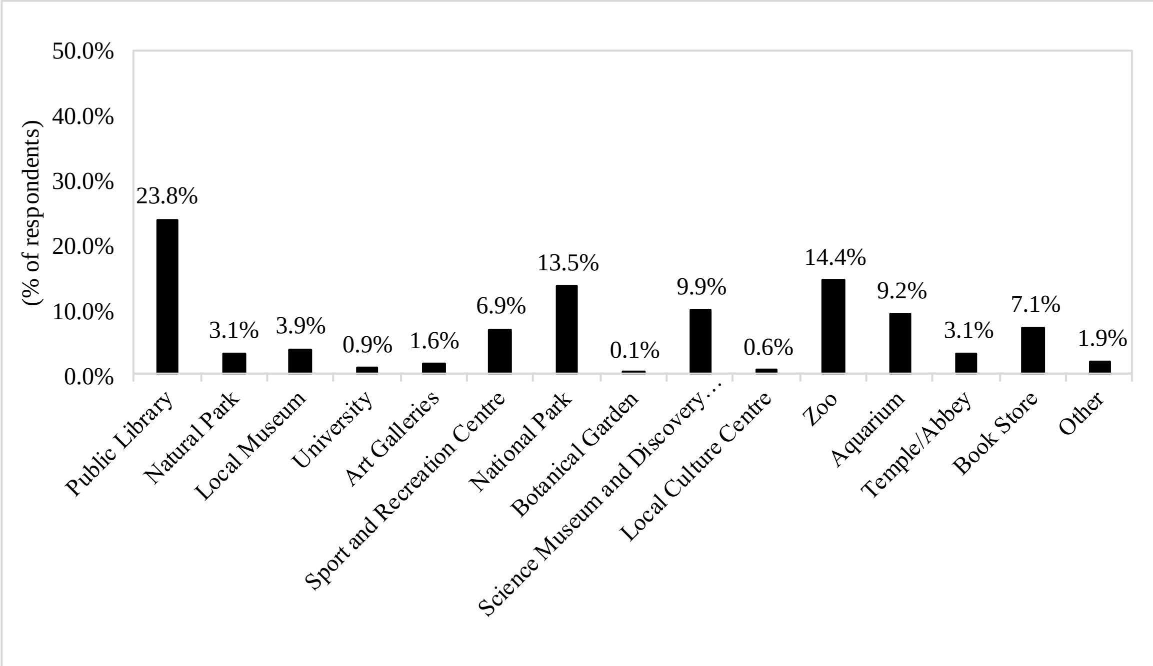
> I often go to the public library for reading books, especially there are a lot of science books there.
> (Panpan, a male primary school student, a host school, the Northeast)

> I went to the public library to use the computer, it helped me search for scientific knowledge to support my science homework.
> (Tongla, a female high school student, a guest school, the Centre)

The next most commonly used informal learning resource was the zoo, at 14.4% (N=201) (see Figure 14). Visiting the zoo prompted participants to learn about animals, the ecosystem, the environment and other features of natural science. The participants' comments mentioned that the animals in the zoo were interesting and that the zoo provided many activities for visitors, including an animal talent show that taught about animals in relation to the environment and human life.

> There are a lot of interesting animals in the zoo. I learnt about animals' lives and how they live, including their habitat and environment. I had a great time visiting the zoo with my family.
> (Pongpan, a male primary school student, a host school, the Centre)

Figure 14: Informal learning resources and settings identified in the responses of all participants



The third setting identified by participants at 13.5% (N=189) (see Figure 14) was the national park. A visit to the national park promoted participants' realisation of the importance of the forest, wildlife and environment. This activity also enabled participants to practice scientific skills, such as nature observation.

> I visited the national park on a school trip. My teacher taught me how to observe the forest, ecosystem and environment including animals. I learnt about the ecosystem of the forest and how animals live in this park, which links with the environment.
> (Ote, a male high school student, a guest school, the Northeast)

5.2.2 Regions

In exploring the informal learning resources of each region, many respondents in the Centre, North and South selected the public library as their favourite informal learning resource, at 27.1% (N=95), 31.7% (N=111) and 22% (N=77), respectively. However, in the Northeast, the national park was the most popular resource for informal learning, at 19.1% (N=67) (see Table 12). The Northeast participants' comments indicated that visiting the national park, which is located near the school, was the main informal learning setting for enhancing science performance and knowledge about natural science in young people in this region. For example, Banpang Wittayakom School in Nakhon Phanom, which is near Phu Lankka National Park, can easily allow their students to learn outside of the classroom through trips and visits.

> My school is located near the Phu Lankka National Park. So I have visited this park every year on school trips to observe nature in the forest, with its animals and different environments. This activity stimulated me to be aware of the importance of nature, forests, the environment and animals.
> (Pang, a male high school student, a host school, the Northeast)

Table 12: Top three informal science learning resources and settings for young people in each region

Top three popular of informal learning resource	The Northeast (N=350)	The North (N=350)	The Centre (N=350)	The South (N=350)
The first most popular	National Park 19.1% (N=67)	public library 31.7% (N=111)	public library 27.1% (N=95)	public library 22.0% (N=77)
The second most popular	Zoo 15.7% (N=55)	National park 23.7% (N=83)	Zoo 20.0% (N= 70)	Science museum and discovery centre 14.9% (N=52)
The third most popular	public library 14.3% (N=50)	Sport and recreation centre 9.7% (N=34)	Sport and recreation centre 8.6% (N=30)	Zoo 13.4% (N=47)

The national park was identified as the second most popular setting for informal learning among the northern participants at 23.7% (N=83). The zoo was identified as the second most popular place among the participants in the northeast and the central regions at 15.7% (N=55) and 20.0% (N=70), respectively. Participants who selected the zoo mentioned that visiting the zoo helped them learn more about animal lives since there were many interesting animals that they have never seen before. They were excited by observing animal behaviour and the environment. This made them enjoy and appreciate those animals.

> I like animals and I like the zoo because there are many animals that I have never seen before. Moreover, I like an elephant. I have learned how wild elephant survive and how big is an elephant.
> (Pom, a male primary school student, a guest school, the Centre)

In the South, the Science Museum and Discovery Centre was the second most popular site for informal learning, with responses at 14.9% (N=52) (see Table 12). The participants' comments about the Science Museum and Discovery Centre indicated that visiting the museum had promoted science learning. The interaction with hands-on science exhibits and activities has helped this participant gain better understanding about science phenomena.

> I visited the National Science Museum with a school trip. I found that playing with hands-on science exhibits helped me gain better understanding of the science that related with my school science curriculum.
> (Petch, a male high school student, a host school, the South)

Another popular informal learning resource was the sport and recreation centre, primarily chosen by participants from the north and centre, at 9.7% (N=34) and 8.6% (N=30) (see Table 12). The sport and recreation centre provides exercise activities and sports equipment for local young participants to promote physical performance development.

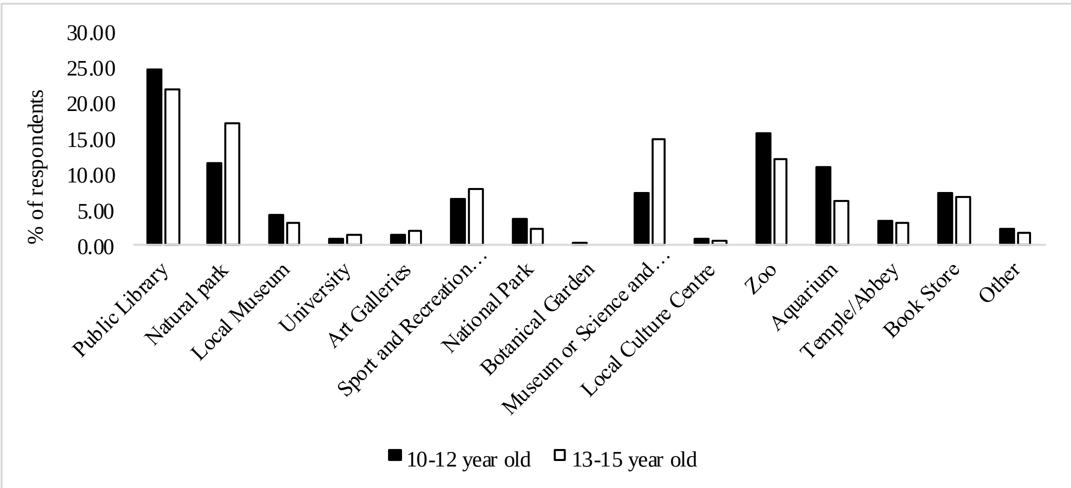
> I like playing sports, especially football. So the sport and recreation centre is my favourite informal learning setting, and I often spend my free time there. I also learnt how to be healthy from the centre staff.
> (Make, a male high school student, a host school, the Centre)

5.2.3 Age

The results of investigating the informal learning resources with respect to the two age groups, namely 10–12 years old and 13–15 years old, showed that the public library was still the most popular informal learning setting for both age groups, at

24.7% (N=228) and 22.0% (N=105), respectively. The zoo was the second preferred setting of the participants aged 10–12 years old at 15.6% (N=144), whereas the national park was the second informal learning setting mentioned amongst participants aged 13–15 years old at 17.2% (N = 82). The third setting of the participants aged 10–12 years old was the national park at 11.6% (N=107). Whilst participants aged 13–15 years old identified Science Museum and Discovery Centre at 14.9% (N=71) (see Figure 15).

Figure 15: Informal learning resources and settings identified in the responses of participants 10–12 years old and 13–15 years old

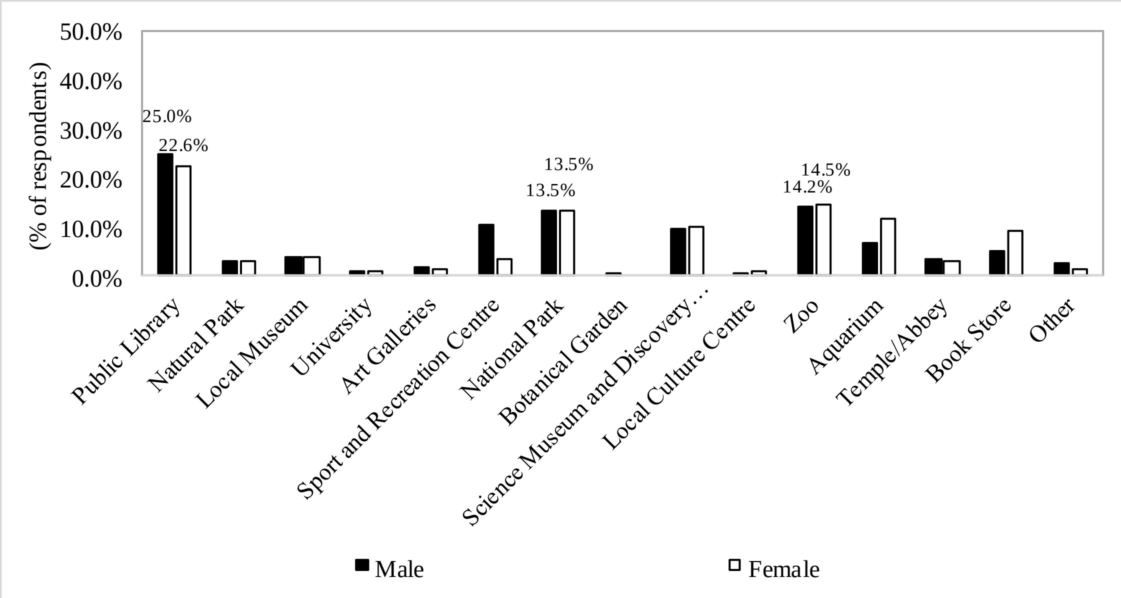


In the teachers interviews it was also apparent that visiting informal science learning settings that are far from a school such as science museums and centres, tended to be provided for older rather than younger students. Tippawan, a female science teaching from the central region, discussed that taking students in junior high school (aged between 13-15 years old) rather than primary school students (aged between 10-12 years old) tended to be more common because of safety and travelling issues associated to making such visits.

5.2.4 Gender

The results exploring the responses of male and female participants showed no statistically significant variations in informal learning resources and settings mentioned between male and female students (see Figure 16).

Figure 16: Informal learning resources and settings identified in the responses of male and female participants



In summary, the public library was the main informal learning setting through which all local participants accessed scientific knowledge and information. However, at the regional level, the national park was the informal learning setting that the Northeast participants most frequently identified, compared to the public library in the three remainding regions.

Other popular informal learning resources were the national park, the zoo, and the sport and recreation centre. Science museum and discovery centres were also considered a valuable resource for promoting young participants' scientific knowledge.

5.3 Interview results: accessing informal science learning resources

This study investigated resources, settings and events for informal science learning available to students to access scientific knowledge outside of school. These results were obtained from the student interview responses to the question, 'Where else could you find out about science?' and 'Are there things you do outside of school to find out more about science? What are they?' In addition, these results were also obtained from the teacher responses to the question, 'Apart from at school, what other ways do your students come into contact with science?' According to these student and teacher responses, 18 settings, five resources, and three events used for informal science learning by young people were discussed (see Table 13).

Table 13 indicates that school libraries, home computers with internet access, and internet cafés were the top three informal learning settings mentioned in the student interviews. The top three teachers' responses were the national park, the public library, and science camps (see Table 13).

The school library was the only school-based informal learning setting mentioned by students. Most students (N=18) (see Table 13) identified school libraries as primary sources of scientific information. They used the library resources to support science learning in their free time when they were in school. For example, Kingkeaw (a female high school student from a guest school of the Northeast) explained her experience dealing with her science homework.

> The school library is important for science learning. There are a lot of science books to help me to do my science homework. I can find more science information in the school library and information on other subjects. The school library is the only learning resource that I use for searching for science information, because in my village, there is no public library or other knowledge centre to support my learning.

Stating a similar opinion, Bambam (a female primary school student from a host school of the North) said that the school library was the most significant learning setting that she and her friends use to access information, because her family cannot afford access to other informal science learning settings such as science museums and science centres. Wuttipong (a male primary school student from a host school of the South) also found science information needed for his homework in the school library.

Table 13: Informal science learning resources, setting and events accessed by local students

Setting	Count		Resource	Count		Event	Count	
	S	T		S	T		S	T
(1) Public library	3	11	(1) Website search engine	4	2	(1) Science camp	1	4
(2) Home: computer and internet	16	1	(2) TV: Science programmes and news	4	-	(2) Science festival	2	3
(3) National park	2	15	(3) Smart phone	-	2	(3) Science competition projects	-	1
(4) Local aquarium	3	1	(4) Family	3	2			
(5) National Science Museum (NSM)	4	1	(5) Local wise men	-	2			
(6) Local administration organisation	2	-						
(7) Internet café	8	-						
(8) Rice fields	2	-						
(9) Zoo	3	-						
(10) Local Science Centre	2	-						
(11) Book store	1	-						
(12) Friend’s home	2	-						
(13) School library	18	-						
(14) Local natural history museum	5	-						
(15) TK Park Mahasarakham	-	1						
(16) Local water plant	-	1						
(17) Local power plant	-	1						
(18) Local canned fruit factory	-	1						

(19)	Rice field	1	-

Note: Count (N = number of response), T = Teacher interview results, S = Student interview results (from Appendix D.4 (1) and D.5 (1).

On the other hand, most responses from teachers (N=15) (see Table 13) mentioned national parks as the key location for informal science learning for local students; identified in 6 responses from the Northeast, 4 responses from the North, 2 responses from the Centre and 3 responses from the South. 8 of these 15 responses mentioned that the location of the school is not far from a national park and therefore the school can easily access the park. For this reason, the schools arrange visits to the park as extra-curricular activities. Bunyapat (a female science teacher from a host school of the Northeast) said that her school is located near the Phulangka Nakhonphanom, an important national park and learning resource for her students. The school arranges an annual visit to the park for its students. This programme encourages students to learn about the ecosystem of the forest, including the importance of the environment and how the forest is related to their daily lives. Moreover, they can practice the scientific method by undertaking observations of nature such as animals and plants in the national park, thereby promoting development of science performance.

The second most popular informal learning resource from the students' results was using a computer with internet access at home, with 16 responses. Gang (a male high school student from a host school of the South) stated that accessing scientific knowledge and information via the internet is a useful method to obtain scientific information.

Additionally, the student results showed that the internet is as important a resource for students as the library. Participants realised the importance of the internet as a quick and easy method for accessing information. 31 responses were linked with using online technology to access science information, which included using free WiFi (from the public library (N=1) and the local administrative organisation (N=2)), internet cafés (N=8), web search engines (N=4), and home computers (N=16) (see Table 13).

Participants mentioned web search engines as a helpful method to enable faster, easier access to scientific information directly related to their science reports and homework. Champ (a male high school student from a guest school of the Northeast) mentioned Google as the main search engine he uses to find interesting topics and useful knowledge, and he also watches interesting science experiments on YouTube. Similarly, Dangthong (a female high school student from a guest school of the North) also stated that she learned science from YouTube on the True PlookPanYa channel. This channel prepares experiments based on the school's science curriculum. Although she does not perform experiments in her class, she is able to observe experiments on this channel.

However, for some students who do not have a computer at home, smart phones are used to access web search engines. They may access the internet from a smart phone or free Wi-Fi from a local administration organisation or the public library. For example, Mam (a female high school student from a host school of the Northeast) mentioned using her parent's smart phone to access information using free Wi-Fi from the local community organisation near her house. She thought that this was a very useful method that helped her to find more information for her homework.

Student results also show that students who had neither a computer nor a smart phone used an internet café service near their homes. 8 student responses mentioned using the internet café service, making it the third most popular way of accessing informal science learning resources for young people that were interviewed (see Table 13). Participants tended to only go to the café when they needed information for their homework, and they spent less than an hour using the internet because of the cost. Keng (a male high school student from a guest school of the Centre) explained his experience using the internet café service.

> I went to the internet café when I wanted to find important information to help with my homework. I do not have a computer at home, and the school library does not have a computer either. The internet café is an important option for me to use to access information, but I only use the café when I need it because its cost is very expensive for me.

Teachers also believed that the public library was an important resource for their pupils, mentioned by 11 teacher responses. The public library tends to have more science books than school libraries. Moreover, students can use computers in public libraries to find more information through accessing the internet, as Wi-Fi is provided without charge. Rawiwan (a female science teacher from a guest school of the North) said that students can use smart phones to access the internet for information such as science news, science experiments, and science practice that supports their science homework. Likewise, Jantima (a female science teacher from a host school of the Northeast) mentioned her experience in the public library. She said that the public library was the best learning setting for her and her students. Students can use computers to search for information about science via web search engines, and searching for new information and useful knowledge from the internet is easier and faster than using books. However, Saksuriya (a male non-science teacher from a guest school in the Centre) stated that there are many science books in the public library, and that it is a useful resource for students to develop their science performance and knowledge. As there is a limit to available computers in the library, science books can also function as inexpensive resources which are available to more users.

Science camps were identified as a useful informal learning space by four teachers from the Centre. These teachers referred to science camps that are run by science teachers in their areas (or parishes). Damrhongsak (a male science teacher from a host school of the Centre) stated that three schools in the parish created a science programme which included a camp lasting three days and two nights for high school students as an annual project. This camp supported science education and preparation for university applications.

At the regional level there were also some additional locations that stood out. In the Northeast, for example, a rice field was stated as an example informal learning space, perhaps as a major occupation in this region is a rice farmer and therefore the young people were likely to have family members in that profession and to be accessing such locations. In Ford’s (a male primary school student from a host school of the Northeast) interview, the student discussed learning about the environment, ecosystems and living things from observing his rice field because he helped his parent or carer to crop sticky rice from the field. Similarly, the power plant, also was offered as a specific informal learning setting by participants in the South, where a teacher stated that the PPT Public Company Limited supported visits to the power plant by junior high school students to learn about the processes of power plants and the significance of power (Ampornpan, a female science teacher from the host school of the South).

In summary, for the students, the three most significant learning resources discovered during these interviews were the school library, home computers and internet cafés. Both home computers and internet cafés were linked with the importance of using the internet and search engines to access scientific information. However, there were also specific examples related with parent’s occupation and local industry, such as the power plant. Additionally, the top three significant learning resources in teacher opinions were the national park, the public library and science camps.

5.4 Questionnaire results: Awareness of the science caravan project

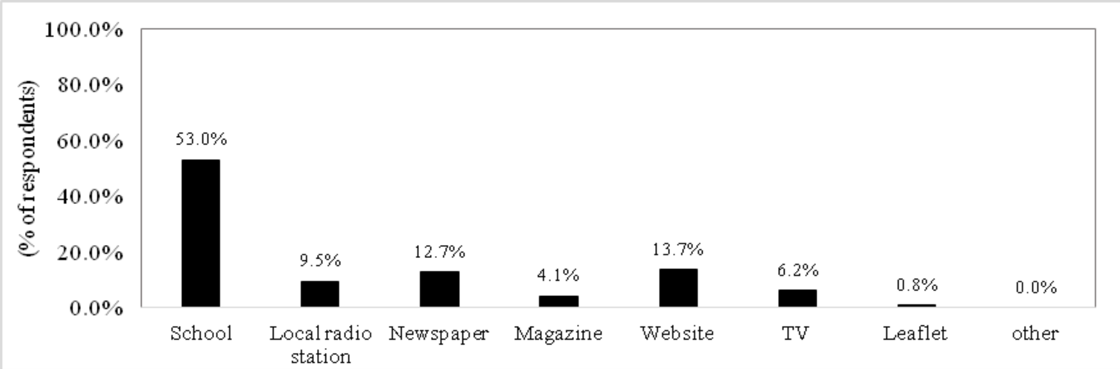
To consider awareness of the Science Caravan project, a series of questions in the pre-questionnaire explored what participants knew about this project before they participated and how they became aware of it. The questionnaire also explored the expectations that participants had of the project before they participated.

5.4.1 Prior knowledge of the Science Caravan project

From the questionnaire results, 70.8% (N=991) of respondents had not heard about the Science Caravan project before participating. Only 29.2% (N=409) knew about the project beforehand. This result was similar across all regions, age and gender. These results were not unexpected. The aim of the Science Caravan is to reach students in remote locations, and such students and their teachers generally lack opportunities to find out about, access or participate in informal science learning events.

As evidenced by Figure 17, 53.0% (N=334) students who knew about the Science Caravan before participating were most likely to indicate that they got the information through their school. This result was similar across all regions, age and gender.

Figure 17: Information resources on the Science Caravan project

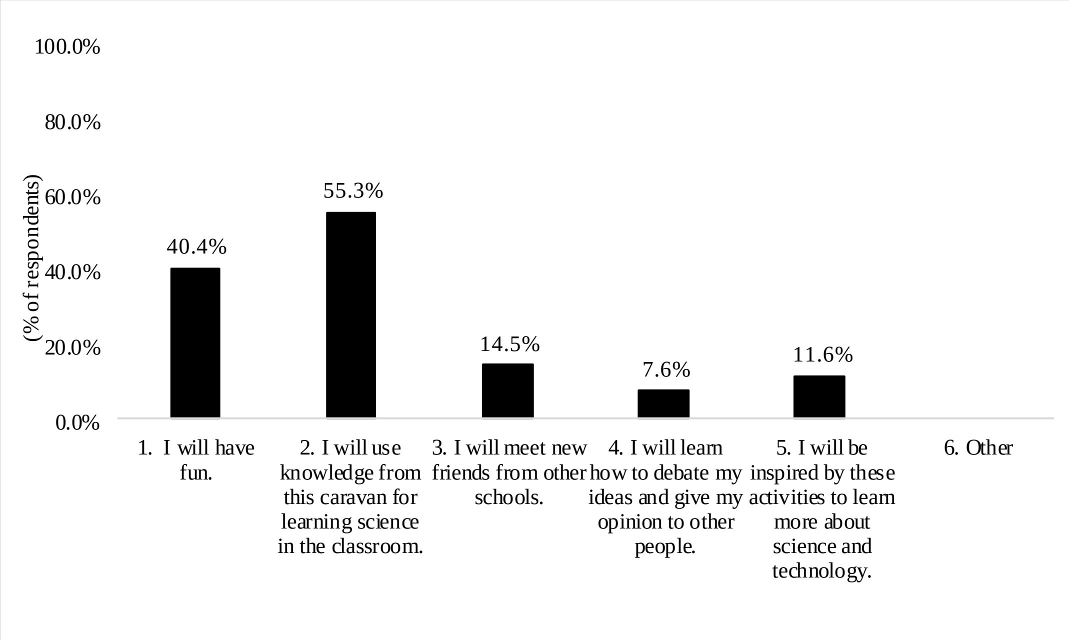


5.4.2 The expectations of participants

(1) All participants

Regarding the expectations participants had of the Science Caravan project, the main expectation was to gain knowledge from the Science Caravan that could be used to promote science learning in the classroom, as identified by 55.3% (N=774) of participants. Having fun was the second expectation that participants indicated, at 40.4% (N=565). Three other expectations, namely meeting new friends, being inspired to learn more about science, and getting the opportunity to present opinions, were noted by less than 15.0% of the participants, at 14.5% (N=203), 11.6% (N=163) and 7.6% (N=107), respectively (see Figure 18).

Figure 18: Expectations of participants prior to involvement in the Science Caravan project



The expectations of local participants were also explored in terms of the participants' regions, age and gender.

(2) Region

As Figure 19 shows, participants from the South, Northeast and Centre mainly expected to gain knowledge from the Science Caravan that would help them learn science in their classrooms, where as in the North, the most prevalent expectation was having fun at 52.6% (N=184), while 37.1% (N=130) expected to use knowledge from this event for learning science in their class. Additionally, examining the difference in data distribution by the Kruskal Wallist Test, found that the *p-value* was lower than 0.05. The data distribution was therefore significantly different. The result shows the northern participants had different expectations to those from other regions.

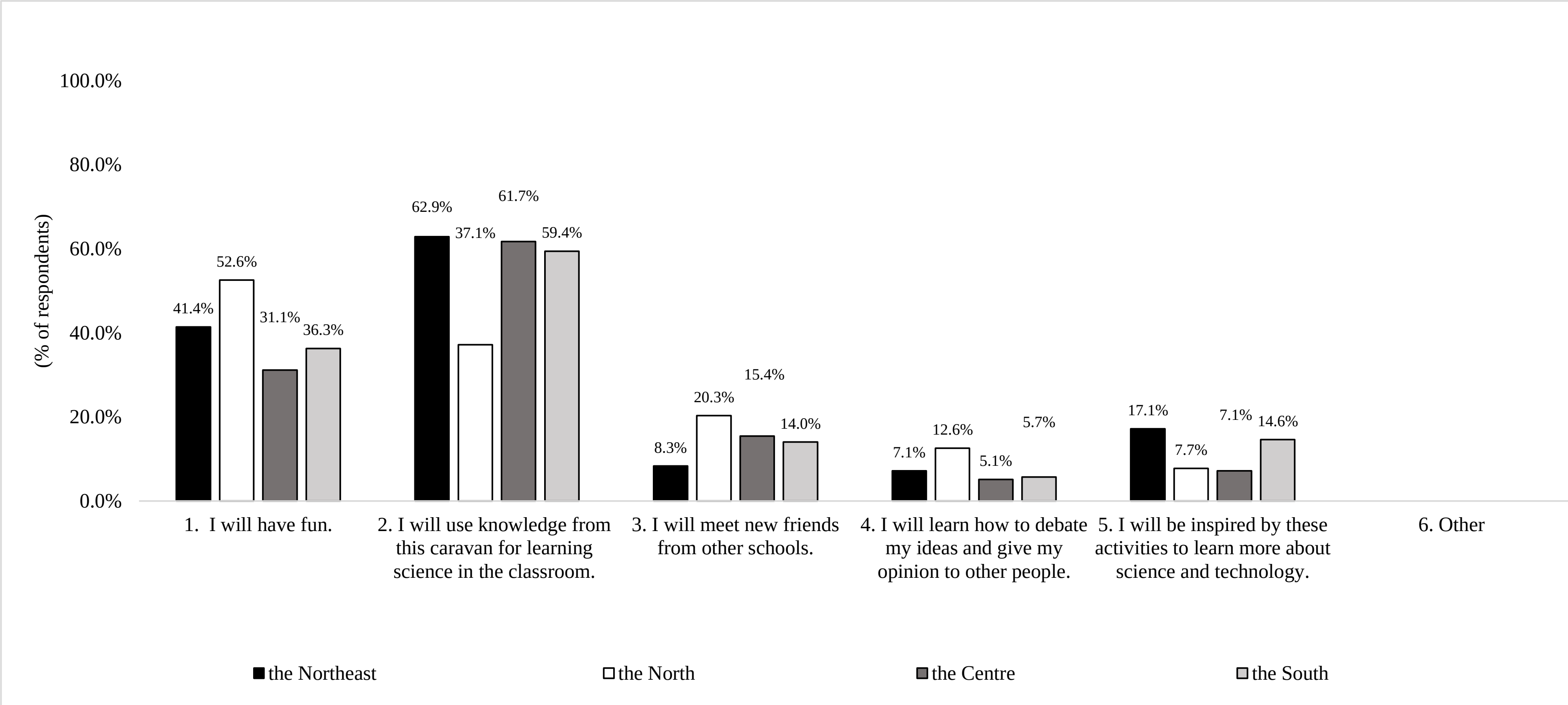
From the student interview data, it was also apparent that students in the North expected to be involved in fun activities and saw it as different to learning in a classroom. Prach (a male primary school student, a guest school, the North) discussed this.

> I hope I will be involved with the Science Caravan again. I hope the next visiting the Science Caravan will have more fun activities and be easy to understand. I hope to watch the funny show like science show. It made me happy and laugh and I learnt many scientific principles from this show.

In contrast some of the students in the South, the Centre and the Northeast appeared to have different expectations, Somsak (a male primary school student, a host school, the South) expressed his expectation for future involvement.

> I hope to participate with the Science Caravan again. I hope the Science Caravan will provide more science activities. I think some existing science activities in the Science Caravan such as Chicken Cup and Science Games were too easy for me. I had been expecting to be involved with more hands-on activities, science experiments. I think it will be useful for supporting my science study in a science classroom.

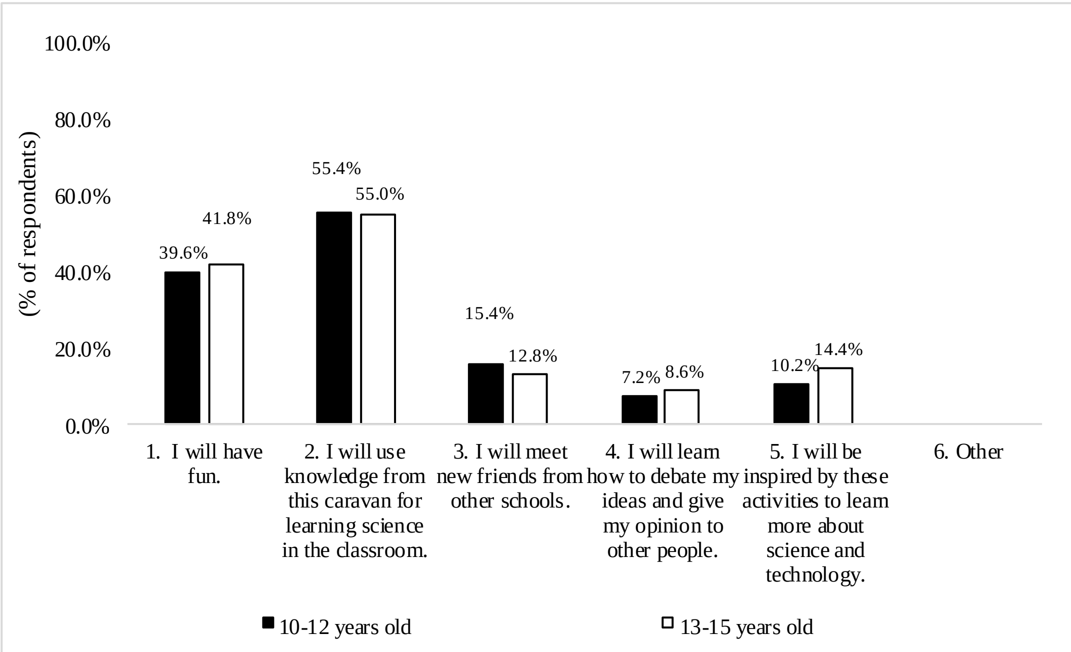
Figure 19: Expectations of participants of each region regarding involvement in the Science Caravan project



(3) Age

Figure 20 shows how age affected the participants' expectations. Both age groups (participants 10–12 years old and 13–15 years old) responded that gaining knowledge from the caravan that could facilitate science learning in a classroom was their main expectation from engagement, at 55.4% (N=511) of participants aged 10–12 years old and 55.0% (N=263) of participants aged 13–15 years old. Both groups also agreed on their second expectation, which was having fun, at 39.6% (N=365) of participants aged 10–12 years old and 41.8% (N=200) of participants aged 13–15 years old.

Figure 20: Expectations of participants of different age groups (10–12 years old and 13–15 years old) regarding involvement in the Science Caravan project



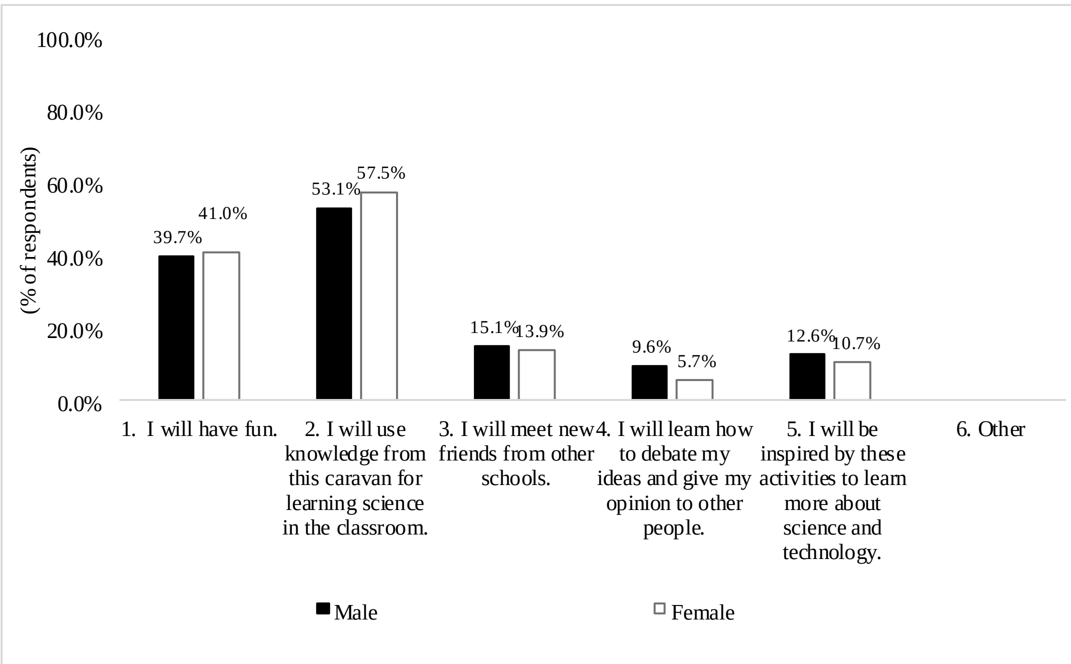
Examining the data distribution of each expectation between both age groups using the Mann-Whitney U test found it was significantly different, with the *p-value* at 0.019 (<0.050). From the result, the responses of both participant groups was only different for expectation 5, "I will be inspired by these activities to learn more about science and technology", respondents aged 13–15 years old ranking expectation 5 more highly (see Figure 20).

(4) Gender

Exploring how gender affected participants' expectations regarding caravan involvement showed that male and female participants responded similarly. The sequence of expectations from most to least expected for both gender groups was the same.

However, in examining the difference in the data distribution between male and female participants using Mann-Whitney U test found that the *p-value* at 0.006 (<0.050) and the data distribution was significantly different. From the result, it showed that the responses of both participants were similar regarding four of the five expectations (1, 2, 3 and 5), but different regarding expectation 4, "I will learn how to debate my ideas and give my opinion to other people with, and male participants more likely to agree with this expectation (see Figure 21).

Figure 21: Expectations of male and female participants regarding involvement in the Science Caravan project



In summary, this section examined responses from all participants, exploring the impact of region, age and gender on their' expectations from the Science Caravan engagement. The results showed that they expected to use scientific knowledge from the Science Caravan to enrich science learning in the classroom. Similar results were found from responses of the northeast, central and southern participants, though most northern participants also expected to have fun from visiting the Science Caravan. Males were more likely to believe that engaging in the Science Caravan would help them learn how to debate ideas and present opinions and there were some small variations in expectations of the Science Caravan on the basis of age group.

5.5 Teachers' expectations of Science Caravan engagement

In exploring previous experiences with the Science Caravan from the teacher interviews, out of 20 teachers, 12 teachers responded they had never been involved with the Science Caravan before, whereas eight teachers identified they had previously been engaged with the Science Caravan.

In examining expectations of Science Caravan engagement, teacher responses to the question 'Why did you decide to participate on this occasion?' identified teachers' expectations of engagement can be divided into three expectations: obtaining new scientific knowledge (N=2); experience learning with hands-on science exhibits (N=14); and motivation (N=4).

5.5.1 New scientific knowledge

From the teachers' interviews, two responses (from the North and the Centre) stated that teachers and students may obtain new scientific knowledge from participation in the Science Caravan. Rawiwan (a female science teacher from a guest school of the North) confirmed this. She believed that the activities in the Science Caravan may present science and technology that students have never seen before.

5.5.2 Science hands-on exhibit experiences

Most teachers (N=14) expected that engaging with the Science Caravan would be a good opportunity to promote students in gaining more practice in science experiments and self-learning by interacting with hands-on exhibits. Bunyapat (a female science teacher from a host school of the Northeast) explained that in visiting the NSM last year, her students had opportunities to interact with many hands-on science exhibitions. These exhibits supported science learning for students in school because the exhibits' contents were related to the school's science curriculum. Additionally, interaction with the exhibits also supported students in gaining a better understanding of science beyond merely reading from books and watching television. Bunyapat added that in a similar way to visiting the NSM, involvement with the

Science Caravan is a good opportunity to promote student interaction with hands-on science exhibits.

5.5.3 Motivation

Four teachers' responses identified that engagement with the Science Caravan may encourage participants to have a more positive attitude and interest in science and technology. Jitree (a female science teacher from a host school of the Centre) mentioned that learning in informal learning environments encourages students to gain a better understanding of science and become more interested in the subject. Therefore, involvement in the Science Caravan may encourage students to have more positive attitudes and become more interested in the facets of science and technology. She believed that the informal learning atmosphere, activities, and the NSM staff work together to stimulate her students' interest in science.

Chapter summary

This chapter identifies the settings or resources available to young people for informal science learning at the regional level as well as their expectations prior to engagement in the Science Caravan project as one opportunity for an informal science learning experience. The results can be summarised into three main points as follows.

Firstly, the questionnaire results showed the public library was the most significant informal learning setting outside of school identified through both the pupil and this was also echoed in the teacher interviews. The results from the student interviews, also showed that school library is also an important resource. Moreover, the student interview results showed that use of the internet to access scientific knowledge, news and information, is also a crucial resource to support their formal science learning and one which they are often engaging with via traditional informal learning settings (like the library) but which could be overlooked by those supporting education, such as teachers. In terms of specific informal learning settings, local employment settings such as the rice field and power plants were also mentioned in some specific regions. However, the quantitative data found national parks, the zoos, the science museums and discovery centres, sport and recreation centres to also be important resources for participants.

Secondly, the most popular sources for informal science learning suggested location (e.g. proximity to home/schools), accessibility (e.g. cost to visit) and usefulness (e.g. to homework) could all be influences in regards to uptake and that some settings may be useful for informal science learning despite being very loosely associated to science itself.

Finally, in that regard student expectations as to what informal science learning might comprise were not necessarily high, few were previously aware of the Science Caravan project but were keen to learn from, as well as enjoy, the experience, particularly participants in the North. Though, teachers had expectations that it would improve knowledge, access to science experimentation and motivation.

Chapter 6
Factors Affecting Thai Young People and Informal Science Learning

Overview

This chapter presents the factors affecting the informal science learning experiences of participants and addresses research question 2, '*What are the main factors affecting young people's experience of informal science learning?'* In this chapter, seven key factors that affect the science learning experiences of young participants are explored: school, teachers, family, friends, government and other organisations.

6. Factors affecting the informal science learning experiences

This study explored factors that affect informal science learning experiences of students through the student interviews, teacher interviews and NSM staff interviews. From the students' results, these factors were identified in their answers to the questions 'Where else could you find out about science?' (N=18) and 'Are there things you do outside of school to find out more about science?' (N=37). The teachers' results mentioned these factors in their answers to the questions: 'How is science taught in your school?' (N=4), 'Apart from at school, what other ways do your students come into contact with science?' (N=12), 'Are there ways that traditional Thai beliefs affect students' learning around science?' (N=17) and, 'What could give students more access to science locally?' (N=12). Additionally, two responses from the NSM staff mentioned factors affecting informal science learning in answer to the question 'From your experience, how do young students participate in each science activity in each region (learning behaviours and learning styles)?'

From the combined interview results of students, teachers and NSM staff, 7 significant factors that affect informal science learning experiences were identified and these included : (1) schools (N=40), (2) teachers (N=18), (3) family (N=25), (4) friends (N=2), (5) government (N=4), (6) other organisations (N=7), and (7) other young people (N=4). These factors influence informal science learning experiences by either supporting or inhibiting the capacity to learn science in a particular environment.

6.1 School

Unsurprisingly, the interview results indicated that school plays an important role in encouraging science learning, although the ways that schools support learning is nuanced and there is a need for support from outside the classroom. In the interviews, three main ways in which school promotes science learning were raised: School is a main source of support for engaging participation in informal science learning settings and events (N=15); school is a provider of informal science learning programmes such as science camps (N=1); and school is a main resource for science books and media to support student science learning in their free time (N=24).

6.1.1 Promoting engagement with informal science learning settings and events

In the interview results, three teachers mentioned a school policy of promoting learning outside of school and engagement with science activities as an important mechanism to support science learning for young people. This policy aims to promote the policy of the Ministry of Education of supporting student science learning and development. Therefore, visiting informal learning settings was included in school science curriculums. Examples of these settings include Thailand’s National Science Museum (NSM), national parks, local aquariums and zoos.

Tippawan (a female science teacher from a guest school of the Centre) stated that her school has supported high school students (50 students a year) to visit the NSM to support science learning. This setting provided interesting science activities and exhibitions to support science performance. Visiting students can obtain knowledge by experimenting and interacting with the hands-on exhibits. These activities also support students’ basic research skills. The promotion of students’ science learning in a quality informal science learning institution can support their learning development.

From the students’ results (N=12), the ability to visit the informal science learning setting was provided by the local school for students who may otherwise have no opportunity to visit these settings. For example, Amitta (a female primary school student from a guest school of the North) indicated that the experience of engagement with visiting the NSM in the previous year with her school was her first opportunity to travel to visit the NSM. She has not had a chance to support her learning through any informal environment because her family has limited funds.

6.1.2 Resources for science books and media to support student science learning in their free time

Furthermore, the results from students' responses (N=24) demonstrated that the school provides science books and media to support student science learning. These resources are collected in the school library. This library is the only learning resource available for students in some remote schools who have limited financial resources, and local students who live far away from the public library (see Chapter 5 section 5.3). Som (a female primary school student from a host school of the Centre) mentioned using learning resources in the school library to promote her science learning.

> I only went to a school library because my house is far from the public library and my parents cannot support visits to informal learning environments. The school library is the only place I use to study outside of a classroom. The library has a lot of science books and computers to use to search for information. Also, there are a lot of science Video and DVDs, especially animals, plants and cosmology for students. They can borrow these media for watching at home or they can watch these media at the school library.

Similar to this opinion, Ote (a male primary school student from a host school of the Northeast) explained how he did science homework and obtained scientific knowledge outside a classroom. Ote stated that the school library is the main resource of scientific knowledge because his village has no informal learning setting such as the public library. He uses the books in the school library to do science homework. However, he said that due to limited school funding, the learning materials available cannot meet students' needs, and most books have outdated content.

6.1.3 Providers of informal science learning programmes such as science camps

According to the teacher responses, some local schools are the providers of informal learning programmes. They have attempted to create informal science learning programmes, such as science camps, to support science learning in schools. Such programmes can support the involvement of a certain number of students in science activities, and they are helpful for increasing opportunities for science learning in informal environments. For example, Amponpan (a female science teacher from a host school of the South) explained her experience in her school's annual science camp hosted by science teachers. Amponpan emphasised that this camp is an important opportunity for everyone to engage in informal science learning which supports students in developing their science performance.

Unsurprisingly, the school is a key factor in supporting science learning, including providing a pathway to many of the informal learning resources identified in Chapter 5, and providing learning opportunities in unconventional ways.

6.2 Teachers

Teachers were seen to have a significant impact on students' science performance. 18 responses from students, teachers and NSM staff mentioned teachers as the main resources for science knowledge, and/or teachers having an important role in encouraging students to be involved with informal learning, such as supporting students' to obtain knowledge during engagement with such activities.

6.2.1 Teachers as supporters of science learning

For students, teachers are the main supporters of their science learning. Teachers can support students in finding solutions to science problems by supporting knowledge, retention, and understanding. The results from seven teacher responses identified the teacher as a key person who can help local students obtain scientific knowledge and deeper understanding. Saksit (a male science teacher from a host school of the South) specified the importance of the role of teachers, especially science teachers. From his experience, science is perhaps the most difficult subject for students, and most students never develop high performance in the subject. He felt students could ask their science teachers for clarification to promote a better understanding of science, and that it is also important for teachers to search for and develop new teaching techniques to develop students' science knowledge and skills. In a similar opinion, Jantima (a female science teacher from a host school of the Northeast) also mentioned that science teachers are key assistants to the development of science knowledge among students. Unfortunately, in the Northeast, the science teacher shortage is affecting the development of quality science teaching and learning.

Student responses (N=7) also identified teachers as the most important supporters of their science learning. Nim (a female primary school student from a host school of the Northeast) described her experiences doing science homework.

> I often ask my science teacher when I have questions about science and she is able to give me clear answers that support my homework. Moreover, if I have any science questions, I also ask my teacher because she can help me understand science phenomena and how they link with daily life. Additionally, asking teachers is better than searching in library books because these books are out of date.

The role of teachers is not limited to supporting science learning in schools. Teachers also play a significant role in encouraging students' interest in informal learning, and they aid in students gaining better comprehension from participating in these activities.

6.2.2 Teachers as supporters when visiting informal science learning settings

According to student, teacher and NSM staff interviews, teachers' support of science learning for young people during visits to informal science learning projects, such as NSM and the Science Caravan, has an important influence on retention and understanding of science information. One response from a northeast student, one response from a southern teacher from the and two responses from the NSM staff identified teachers as significant helpers in obtaining knowledge from participation in informal learning activities. For example, Prayuk (a science communicator of the NSM staff) responded that teachers who support students during involvement with the Science Caravan can help their students obtain knowledge and better understanding, whereas students whose teachers left them with the caravan on their own may lack the attention needed to engage with the caravan.

> From my caravan experiences, I found that some teachers who come with their students show an interest in the science activities of the caravan. These teachers try to stimulate their students to get involved with activities, and they provide supporting knowledge and explanations to their students when the students have questions or are unable to play with the hands-on exhibits. Teachers can also be translators for students who are in minority groups, most of which are from the North of Thailand. They help students play with the exhibits and get involved with other activities. However, other teachers choose not to partake in activities and leave students in the caravan alone. Most students in this case lack the attention to get involved with the science activities. When they have questions in an exhibit or face difficulty, they tend to leave the exhibit and play at another one. The knowledge development of these students may be lower than that of the first group.

In the student interview data, a Northeast student also mentioned how their teachers could help them learn from the Science Caravan, sometimes expressing that it was difficult to ask the NSM explainers directly, whereas asking their teachers was something they were more comfortable to do.

> I want my teacher to explain to me about the exhibition and teach me how to play and learn. I found it difficult to ask the NSM staff directly. I felt I was not familiar with them, and I have to respect them and be considerate to them because they are my school guest.
>
> (Nim, a female primary school student, a host school, the Northeast)

Therefore, teacher participation in promoting science learning is significant. Teachers are the main resource of scientific knowledge for their students, and act as supporters who help students to find answers to science questions. Teachers also have a vital role to play in promoting science learning during visits to informal science learning venues.

6.3 Family

The results from teacher and student interviews indicated that family is another factor affecting science learning. Family either promotes or hinders science education for students. In promoting science learning, there were two topics mentioned: supporting science homework (N=16) and supporting visits to informal learning science settings (N=5). Teachers (N=4) also identified that family can be an obstacle to children’s science learning if their parents promote superstition.

6.3.1 Supporting scientific knowledge for children

In the interview data, 14 responses were found from teachers and two responses from students which indicated a family influence on science learning. Family members, particularly parents, are key supporters of science learning. Golf (a male primary school student from a host school of the Centre) explained that his father helps him to do science homework and explains the natural science phenomena in daily life. Moreover, his older sister also helps him to find the answers to science questions. Additionally, Navin (a male high school student from a host school of the Centre) mentioned that his family has supportive learning materials, such as a home computer, that help him to complete science homework and study interesting science and technology. Furthermore, Anupong (a male science teacher from a guest school of the North) stated that parents and family members are significant knowledge resources for children. Family members are the first supporters that children tend to ask for help when doing homework. In many local families, parents realise the importance of science and technology in everyday life, so that they take an active role in promoting science learning and developing science performance for their children.

6.3.2 Family visits to informal learning science settings

Families that promote visits to informal learning institutes for children can encourage them to obtain knowledge and develop their learning, though this element was mentioned only by five students. Although many local families have limited budgets to support informal science learning opportunities for their children, some parents who realise the importance of science education, and who can afford the expenses, visit informal learning settings such as museums, zoos and aquariums with their children. Soratree (a female high school student from a host school of the North) described her experience of visiting the NSM.

> My parents want to provide me and my younger brother with good opportunities to learn outside of school, so my family went to the NSM last summer. There were a lot of hands-on science exhibits, and my brother and I enjoyed playing with every exhibit there. Visiting the NSM helped me to learn a lot of scientific knowledge, and I also discovered how to link this knowledge to daily life.

6.3.3 Families and the role of superstition

Teachers (N=4) indicated that family could also hinder science learning. The influence of family on learning can be detrimental, as some families indoctrinate their children in traditional Thai beliefs. Some underserved young people who lack access to basic technologies such as radio and television still tend to believe in superstitions (Jantima, femalescience teacher, host school, the Northeast). These families may encourage pupils to reject scientific knowledge which contradicts traditional beliefs. Chompunuch (a female non-science teacher from a guest school of the South) reported a few representative experiences. She found that students with parents who believe in superstitions trust their parents over the scientific knowledge presented by teachers. For example, one local belief is that animals with disfigured bodies, such as a pig with two heads, can be gods that they need respect, and parents may reinforce this belief in their children. Similarly, Manop (a male science teacher from a guest school of the Northeast) also mentioned that teaching science to students who have strong beliefs in superstitions is difficult. In these cases, teachers are challenged to be patient in affirming knowledge to students, and teachers also needed to support and provide information for young people to explain to their parents who believed in such superstitions.

Therefore, family is a key provider of learning support in terms of promoting informal learning opportunities and supporting knowledge and learning material for young people. However, family can also hinder the science performance of students due to the superstitious beliefs of some families who lack opportunities to access scientific knowledge.

6.4 Friends

Friends were mentioned as a resource by two students in the North and the Centre. The results illustrated that asking for and sharing knowledge with friends can support students doing science homework, especially group research projects. Moreover, some friends' homes may allow access to a computer with internet access which may be useful for doing science research, homework and accessing interesting knowledge. Chunsuda (a female high school student from a host school of the North) stated that asking for help from a friend who has the best performance in science in her class is a useful method to help her gain a better understanding of science. Asking a friend, she added, is more comfortable for her than asking a teacher. Additionally, Preaw (a female primary school from a guest school of the Centre) mentioned that doing science homework with a friend at her friend's home supports her science learning because her friend's home has a computer.

6.5 Government

The government was mentioned by four teachers as a resource for science learning (from the Northeast, North, Centre and the South) (see Appendix D.5, (2.4)). All four respondents had similar opinions about the government. They believed that providing funding and science teachers for local schools is an important responsibility of the government that promotes effective science learning. Panya (a male science teacher from a host school of the South) believed that the funding from the government is the main factor that could support the development of science education for local young people. This funding can support schools in providing effective science learning materials and resources, such as increasing the number of students visiting informal learning institutes. Moreover, Janthima (a female science teacher from a guest school of the South) indicated promoting an increase in the number of science teachers for local schools would also be important to student science learning. These science teachers can help schools provide effective science teaching and learning methods for local students.

6.6 Other organisations

Other organisations play an important role in supporting science education. Three institutes were mentioned in seven teacher responses: local community organisations such as administrative organisations (N=2), local universities (N=2) and private companies such as the PTT Public Company Limited (N=3).

6.6.1 Local administrative organisations

Local administrative organisations have provided workshops for local people on traditional wisdom such as food preservation, local weaving and organic farming. Some local schools added workshops for students designed to conserve traditional wisdom, and much of this traditional wisdom can be linked with scientific knowledge in a classroom. Chumpunuch (a female non-science teacher from a guest school of the South) indicated that her high school students participated in a local community workshop about food preservation. Students also learned about the science behind food preservation from their teachers. This programme supports social stability and unity for the local community, as young children can learn from elders, and elders can gain more understanding of their children.

6.6.2 Local universities

Only two responses from teachers in the North identified local universities as a main supportive setting for student learning and indicated that they provide workshops for teachers to support the development of science teaching. Pongpat (a male non-science teacher from a host school of the North) gave an account of his experiences participating in the science teaching workshop of Naresuan University in Phitsanulok. Pongpat, who has no science background, stated that this useful workshop encouraged him to develop his science teaching skills. Many techniques from the workshop helped him design simple activities related to science curriculum for his students. Rawiwan (a female science teacher from a guest school of the North) also discussed engagement with Naresuan University in Phitsanulok during Science Week, which is held every August to promote science learning. Science Week features science quiz competitions, experiment activities and Science Games for participating students. In addition, students have the opportunity to share their knowledge and present their science learning alongside students from other schools, which also promotes development of students' social skills. Moreover, this university is located near her school, so she can arrange for the maximum number of students to be involved in the event. This is much easier than trying to arrange visits to other informal learning settings that are more expensive and are difficult to travel to, such as science museums and science centres in Bangkok.

6.6.3 Private companies

Only three responses from teachers in the South mentioned that private companies play an important role in promoting science education by providing funding to visit informal science activities and producing science learning materials for local schools. Amponpan (a female science teacher from a host school of the South) identified the PTT Public Company Limited as the main private company that supports students in Nakhon Si Thammarat. In her opinion, the support from the company has been useful for science education, and it has motivated her students to be interested in science and technology. Most of the students who participate in the PTT activities have been impressed with the science involved and realised the importance of energy.

In summary, the factors which affect informal science learning experiences for students could both support or obstruct their ability to learn science in informal science learning environments. These factors include schools, teachers, family, friends, government, and other organisations.

6.7 Previous skills and knowledge

In addition to these factors limitations in participants' learning opportunities were also found in the teacher interviews when they considered additional constraints to science learning, and the NSM staff interview when the staff mentioned about experiences in the Science Caravn. There were two additional factors that they stated affected young people's learning. First, was poor reading and writing skills (mentioned by two teachers from the Northest), this limitation affects the abilities of some students to learn independently.

> From observation of students' interaction with hands-on exhibition in the Material exhibition room, I found that most primary students who were lack of reading skill interacted with the exhibits directly without reading the instruction on label. So, they handled the exhibits in the wrong way, and they took too long time to understand scientific knowledge from these exhibits. Most of them left these exhibits immediately when they found it too difficult for

> self-learning. So, teachers or explainers should support these students more when they learn from science exhibits and activities.
>
> (Jantima, a female science teacher from a host school of the Northeast)

The second factor is a lack of scientific knowledge. This affects participants' ability to engage in informal science learning activities such as those presented in the Science Caravan. Bunyapat (a female science teacher from a host school of the Northeast) mentioned students who had limited scientific knowledge took too long to understand the science contents in informal science activities and exhibitions. Most of them wasted their time interacting with one or two exhibits trying to find the solutions. Otherwise, some students left the exhibits immediately when they found it was too difficult. So, students with a lack of scientific knowledge might not obtain any knowledge and understating of science from participating in informal science learning activities if they do not meet the student's current capabilities. From the NSM staff Science Caravan experiences, Sirkanya (a female NSM staff member) mentioned the Northeast participants had the lowest performance of reading and writing skills compared with other regions and they also lacked a scientific knowledge background which made it more difficult for them to learn by themselves. Teachers and explainers therefore offered to help them learn and interact with exhibitions and activities in those locations. In contrast Southern participants were highlighted as being more capable to learn by themselves and as having more questions to ask their teachers and explainers, along with more discussion with friends to find out the best answer. Therefore, the limitations of personal previous skills and knowledge also effected engagement in this informal science learning opportunity.

Chapter summary

The results of this chapter address research question 2 *'What are the main factors affecting young people's experience of informal science learning?'* This was found to comprise seven key factors affecting informal science learning experiences of young participants.

The results suggested that school was the main factor affecting informal science learning of young people by promoting informal science learning engagement, providing informal science learning programmes and preparing learning resources for promoting science learning of local youth. Additionally, teachers were a main source of learning resource to support local students' science learning. Students can ask about science questions from their science teachers. Teachers also supported knowledge and explanation for students during involved with informal science learning activities such as those engaging with the Science Caravan. Furthermore, family promoted informal science learning by supporting scientific knowledge for their children, and supporting visits to informal science learning institutes such as science museums, zoos and national parks. However, family can be obstacles to science learning if they promote superstition or do not have the knowledge or resources to offer such informal opportunities. Friends, in terms of support and resources, were also another factor affecting science learning of local young people mentioned by a small number of interviews.

At the broader social level the government influences science learning by providing funding and teachers, whilst other organisations, such as universities and private companies, also have a role to play in providing informal science learning opportunities. Broader issues around educational achievement also affect experiences of informal science learning. Limitations in reading and writing skills, as well as pre-existing scientific knowledge were identified as potential obstacles to science learning in formal and informal learning environments, a point which will be further considered in Chapter 7.

Chapter 7

Informal Science Activities and Learning

Overview

This chapter addressed research question 3; *'How do informal science learning activities meet the needs of different demographic groups?'* The results in this chapter are divided into three main sections. The first section presents the scientific background knowledge of participants before and after their engagement with the activities provided in the Science Caravan. The second section shows the survey results obtained after visiting the Science Caravan, which explores specifically the most and least favourite activities amongst young people. The final section investigates participants' interaction with the Science Caravan to obtain knowledge.

7.1 Questionnaire Results: Participant science knowledge background

This section explores scientific knowledge before and after visiting with the Science Caravan ascertained via the pre- and the post-test questionnaire. Thirteen science questions were adapted from the National Survey of Science Knowledge of Thai People (Thailand National Statistic Office, 2008). They were used specifically to investigate any changes in scientific knowledge after involvement in the Science Caravan (see Appendix A.4 and A.5 in the science knowledge background section). The results were analysed from four perspectives: all participants, by region, age and gender.

7.1.1 All participants

The pre- and the post-test for student scientific knowledge resulted in three groups of results. First, 33.1% (N=464) of participants had lower post-test scores than pre-test scores. A smaller number of participants had pre-test scores equal to the post-test score, at 16.6% (N=233). Finally, 50.3% (N=703) of respondents had higher post-test than the pre-test scores. The Wilcoxon signed-rank test was used to examine the differences of the data distribution between the pre- and the post-test results. The pre-test results were significantly different from the post-test results (with the *p-value* of 0.00). The result suggests that participation in Science Caravan activities can increase scientific knowledge.

7.1.2 Region

In investigating each region, all four regions show similar results in that most participants have pre-test scores which were lower than their the post-test scores. There were small variations at the regional level in terms of the numbers of pupils showing improved pre to post test scores (see Table 14).

Using these regional results, the difference in data distribution in the pre-test and the post-test scores was then investigated via the Wilcoxon signed-rank test. This test found that the *p-value* of the Centre, the North and the Northeast is 0.00 and therefore the data distribution was significantly different. However, the *p-value* of the South is 0.713, the data distribution was not different significantly. Participants in the Centre, the North and the Northeast earned post-test scores higher than their pre-test scores. However, in the South, the difference in data distribution between the pre-test and the post-test scores was not large enough to be significant. The changes in scientific knowledge as a result of the caravan were more moderate in the South.

The Kruskal-Wallis test was used to examine the data distribution of the difference in scientific knowledge score before and after participating in the Science Caravan, between the Northeast, the North, the Centre and the South of Thailand. According to the results, the data distribution of the differences in scientific knowledge score between the four regions are significantly different (the *p-value* of 0.000). Participants from the Northeast had the greatest proportion of pupils with post-test score higher than the pre-test score (58.0% or N=203), whereas the South has the lowest number of participants (43.4% or N=152) with the post-test score higher than the pre-test score (see Table 14).

Table 14: Scientific knowledge background of participants from each region

Region	The pre-test score>the post-test score	The pre-test score=the post-test score	The pre-test score<the post test score
The Northeast (N=350)	26.6% (N=93)	15.4% (N=54)	58.0% (N=203)
The North (N=350)	32.6% (N=114)	21.1% (N=74)	46.3% (N=162)
The Centre (N=350)	34.0% (N=119)	12.9% (N=45)	53.1% (N=186)
The South (N=350)	39.4% (N=138)	17.2% (N=60)	43.4% (N=152)

7.1.3 Age

In examining the data distribution of the differences between the pre-test and post-test scientific knowledge scores, the Wilcoxon signed-rank test for each age group; 10-12 years old (primary school student), and 13-15 years old (high school student), was used. This test indicated that the data distribution between the pre-test and post-test scientific knowledge scores for each age group and showed a significant difference with the *p-value* of 0.00 (<0.05). From the result, most participants from all age groups earned significantly higher scores after participating in the Science Caravan.

To explore whether age affects changes in scientific knowledge, the Mann-Whitney U test was used to analyse the difference of the data distribution between primary school students (10 – 12 years old) and high school students (13 – 15 years old) in scientific knowledge score before and after participating in the Science Caravan, no difference of the data distribution was found (p-value at 0.176) (see Table 15) when examining by age group.

Table 15: Scientific knowledge background of participants by age group

Age	The pre-test score<the post-test score	The pre-test score=the post-test score	The pre-test score<the post test score
10-12 years old (N=922)	32.8% (N=302)	16.4% (N=151)	50.8% (N=469)
13-15 years old (N=478)	33.8% (N=162)	17.2% (N=82)	49.0% (N=234)

These results show that participating in the Science Caravan and learning through science activities increases in scientific knowledge for most participants and though there was some variation by region, there were no differences on the basis of age.

7.1.4 Gender

The Mann-Whitney U test was used to examine the data distribution of the difference between the pre and the post score, between male and female young people. The Test showed no significant differences in the data distribution between male and female participants (the *p-value* of 0.620). Female participants having only slightly higher post-test scores higher than their pre-test (see Table 16).

Table 16: Scientific knowledge background of participants by gender

Gender	The pre-test score<the post-test score	The pre-test score=the post-test score	The pre-test score<the post test score
Male (N=697)	35.6% (N=248)	15.1% (N=105)	49.3% (N=344)
Female (N=703)	30.7% (N=216)	18.2% (N=128)	51.1% (N=359)

7.2 Experiences of participating in the Science Caravan project

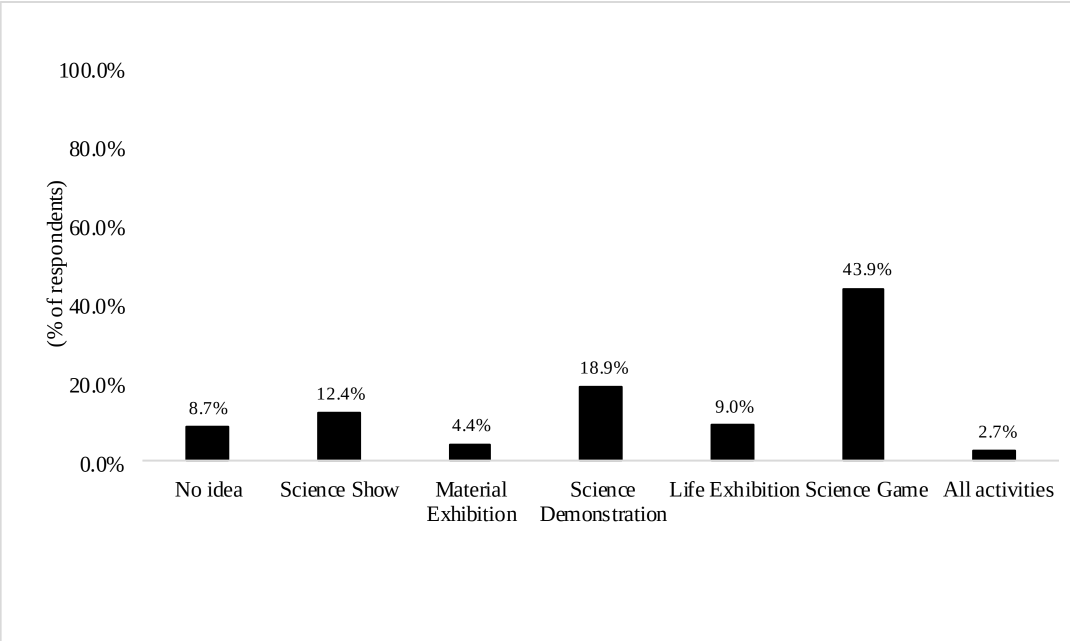
The results in this section considered participants opinions of the Science Caravan activities, including those that were seen to be most well favoured amongst participants and those which they least preferred.

7.2.1 Favourite activities

(1) All of participants

Based on the views of all participants (N=1,400), the Science Games were the most popular activity by far, at 43.9% (N=615) (see Figure 22), followed by the Science Demonstration (18.9% (N=265)) and the Science Show at 12.4% (N=173). 2.7% (N=38) of participants enjoyed all of the activities equally (see Figure 22).

Figure 22: Favourite science activities of all participants

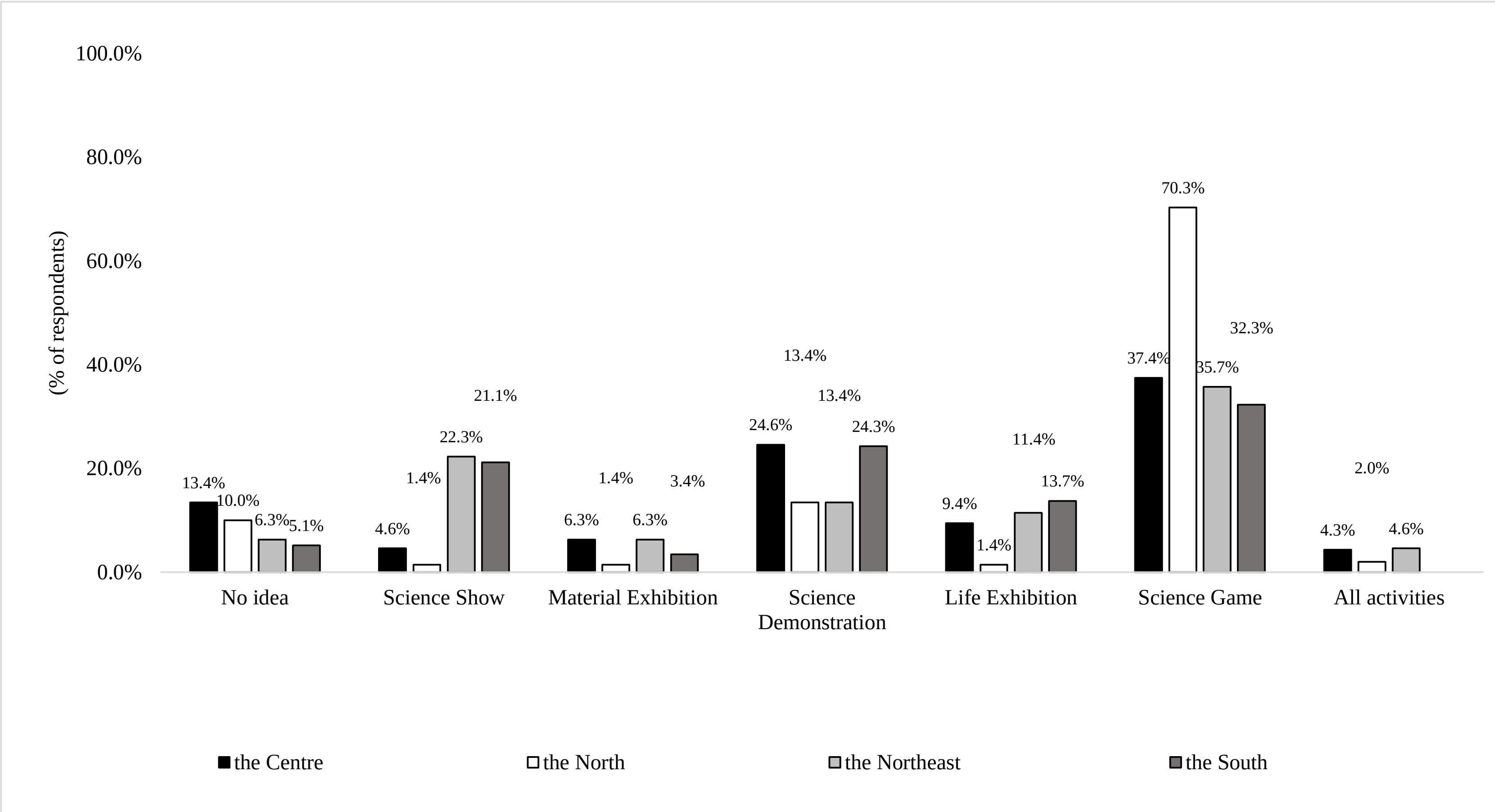


(2) Region

Investigating the difference in the data distribution in participants' favourite activities over the four regions, the Kruskal Wallis Test was used. The data distribution in terms of the favourite activity between the four regions was significantly different, with the p-value of 0.000 (<0.050).

From the results, participants from the North had a far greater preference for the Science Games and did not seem to rate the Science Show, the Material Exhibition and the Life Exhibition amongst their favourite activities. The other regions showed more similar patterns of responses, though the Material Exhibition seemed less popular with pupils from the North and South, and Science Show for the central participants (see Figure 23).

Figure 23: The favourite science activities of participants in each region



According to interview respondents, one reason the Science Games were popular is because a range of games, such as Science Bingo, Tangram, Chicken Voice and Ping-Pong Flying, were available. Pupils also liked the competitive element of the games.

> My favourite game was Chicken Voice. I created a chicken from an ice cream cup, thread and toothpick. I enjoyed the sound from playing the chicken because it sounded like a real chicken and it had a very funny voice.
> (Sangthong, a female primary school student, a guest school, the North)

> I liked the competition and presents involved. Tangram was my most favourite activity. It challenged me to create many patterns from seven pieces of geometric shapes, and I competed with other students.
> (Pom, a male high school student, a host school, the North)

The Science Demonstration was the second favourite activity among participants in all regions bar except the Northeast. Reasons given by respondents included because they found the competition element of the activity amusing, and they also has a chance to do the science experiments.

> I liked the balloon experiment in the Science Demonstration. It made me curious about why I was able to blow up the balloon in my bottle when my friend could not blow up her balloon. During the activity we tried to compete with each other, and I found that it was difficult, but very funny because my friend's face was so funny when she tried to blow into her balloon.
> (Petch, a female high school student, a host school, the Centre)

> I like doing science experiment, and I also like the balloon experiment in the Science Demonstration because I did the

> experiment to find out why the water balloon was not broken when I put the fire burned this balloon.
>
> (Wuttipong, a male primary school student, a host school, the South)

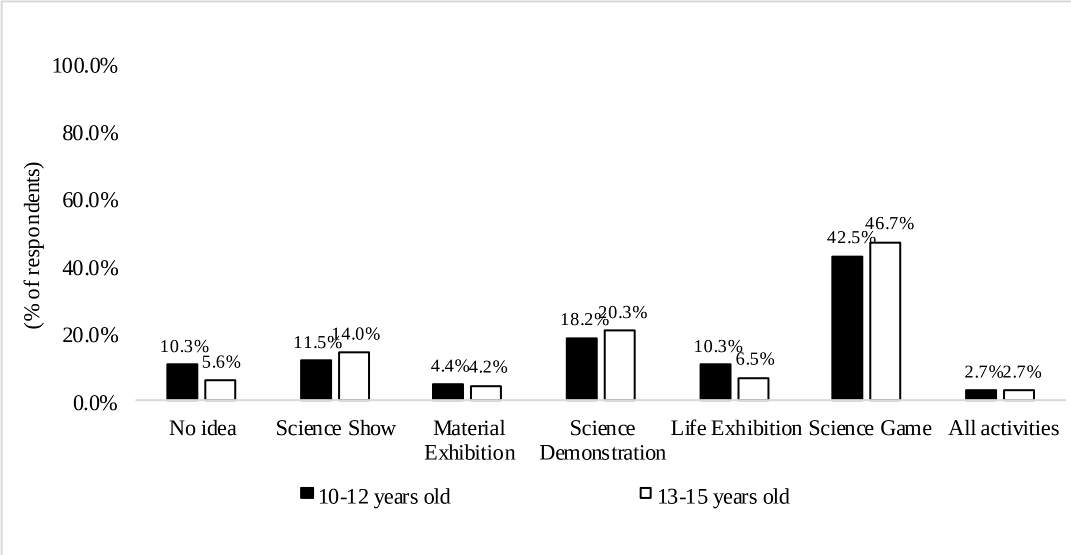
The Science Show was the second favourite science activity of participants from the Northeast, at 22.3% (N=78). The participants who enjoyed this activity provided two reasons for this. The main reason was the humour of the demonstrator of the Science Show, and the second reason was the excitement and mystery of the experiments.

> I liked the Science Show because P-Oah was a funny demonstrator. She made me laugh and feel involved during her show. Additionally, the tin bomb experiment and the compressed bottle with fire were very exciting shows that I have never seen before.
> (Ball, a male primary school student, a host school, the Northeast)

(3) Age

This section investigates the favourite science activity of two different age groups, namely respondents aged 10–12 years old and 13–15 years old. From the Mann-Whitney U Test, the data distribution between younger and older groups was not significantly different (the *p-value* was 0.088). Both age groups also liked the Science Game most (see Figure 24).

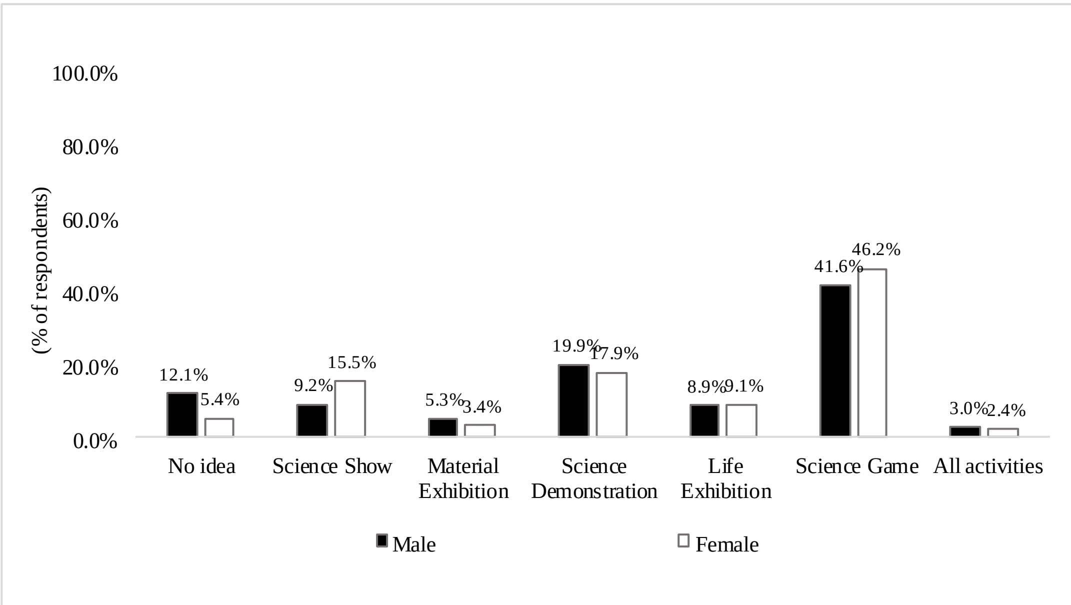
Figure 24: Favourite science activities of participants in different age groups (10–12 years old and 13–15 years old)



(4) Gender

Likewise, the Mann-Whiteney U Test showed that the data distribution between male and female participants showed no significant difference (*p-value* of 0.177) (see Figure 25) Male and female also identified that the Science Game was their favourite activity.

Figure 25: The favourite science activities of male and female participants



7.2.2 Least favourite science activity

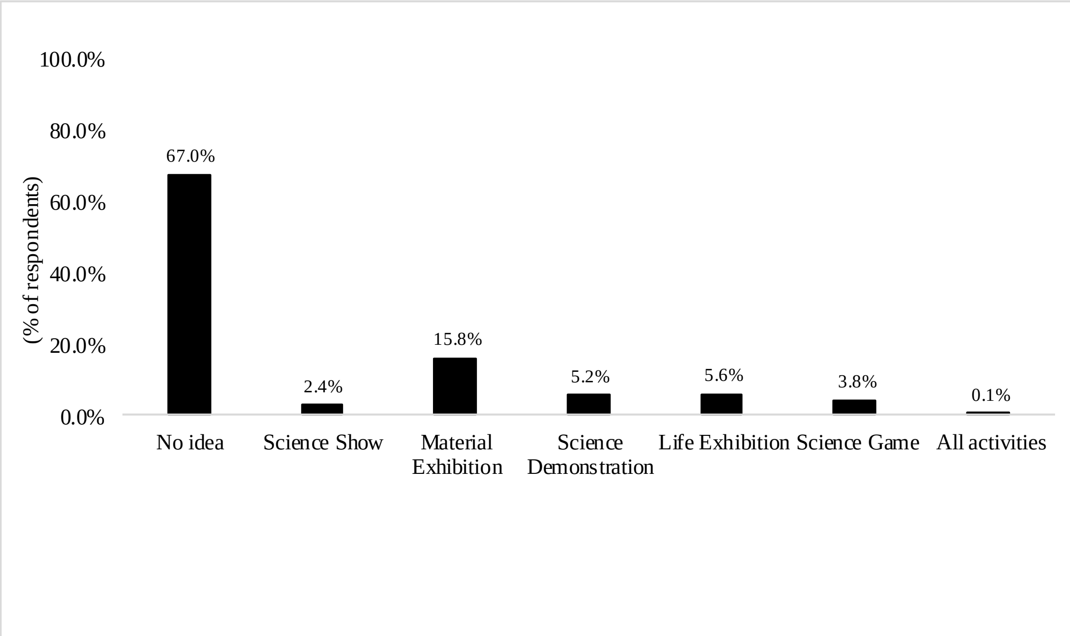
(1) All participants

In the exploration of the least favourite activities of all participants, most participants (67.0% (N=938)) selected the "No idea" box. This result indicates that most participants enjoyed the informal science activities in the Science Caravan. Amongst those who indicated a least favourite activity, the Material Exhibition had the highest percentage, at 15.8% (N=221) (see Figure 26). The participants' comments in the post-questionnaire in response to question 7 stated that the information on the label of the exhibition made it difficult for many participants to use on their own and most students had to ask for help.

> I think learning on my own was too difficult with the Material Exhibition. I didn't understand the instructions on the label, so I couldn't play with many exhibits in the Material Exhibition room.
> (Soda, a male primary school student, a host school, the Northeast)

> I don't like the Material Exhibition because it was too difficult to play exhibits by myself. I don't understand the instruction on the exhibition labels. I needed the explainer help me play these exhibits.
> (Tom, a primary school student, a guest school from the North)

Figure 26: Least favourite activity of all participants



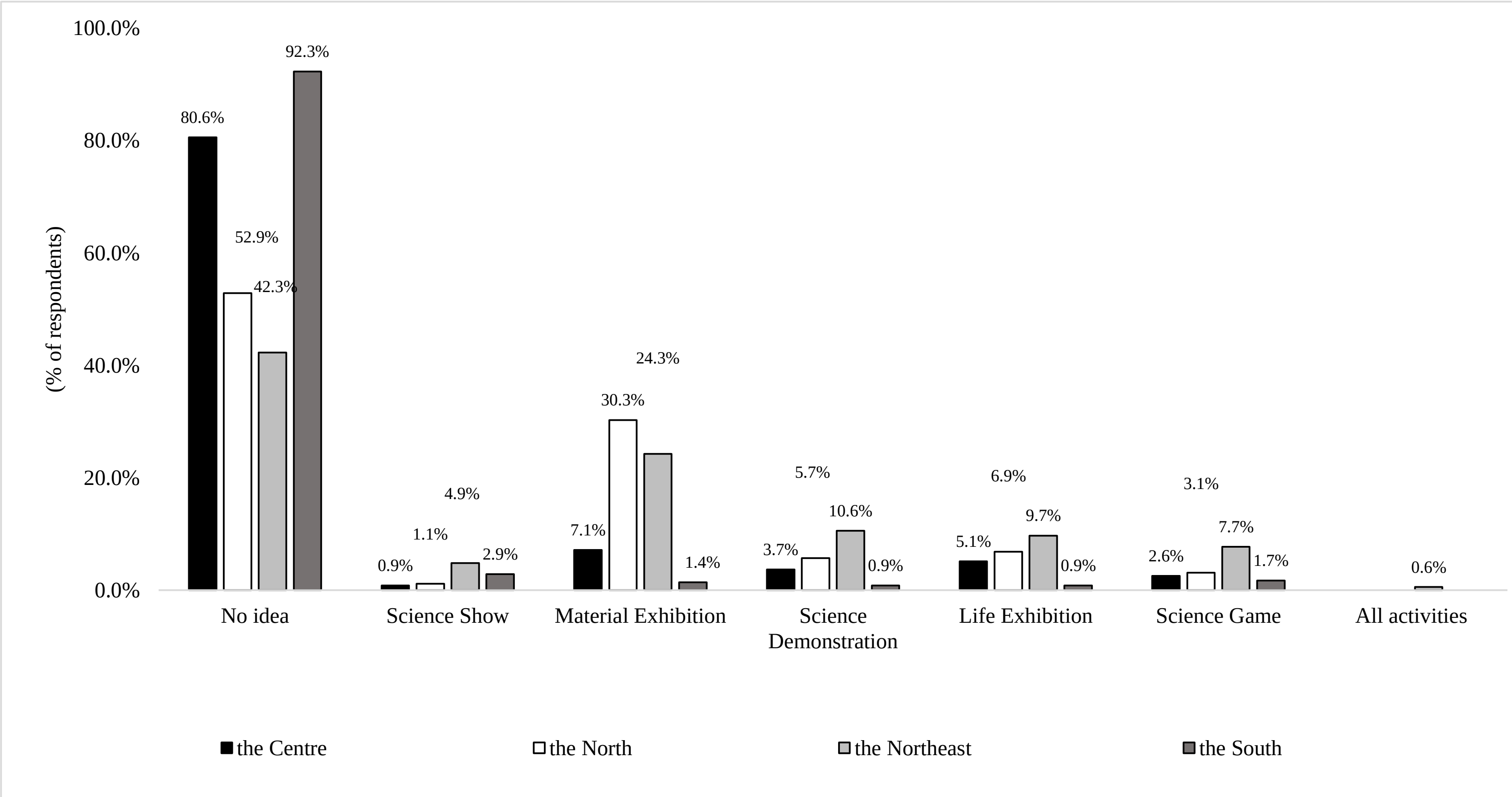
(2) Region

The Kruskal Wallis Test showed significant differences in the data distribution between the regions in terms of the activities that they liked least (the *p-value* of 0.000). As shown in Figure 27, in three regions, participants noted the Material Exhibition as their least favourite science activity though to quite varying degrees, at 30.3% (N=106) of all the Northern, 24.3% (N=85) of all the Northeast and 7.1% (N=25) of all the Central region participants.

On the other hand, the Science Show was the least favourite activity for the Southern participants at 2.9% (N=10). The participants' commented that the noise and perceived danger of the bomb experiment made some participants uncomfortable and frightened.

> I didn't like the Science Show because the tin bomb was too dangerous, and it was very noisy.
> (Prang, a female primary school students, a host school of the South)

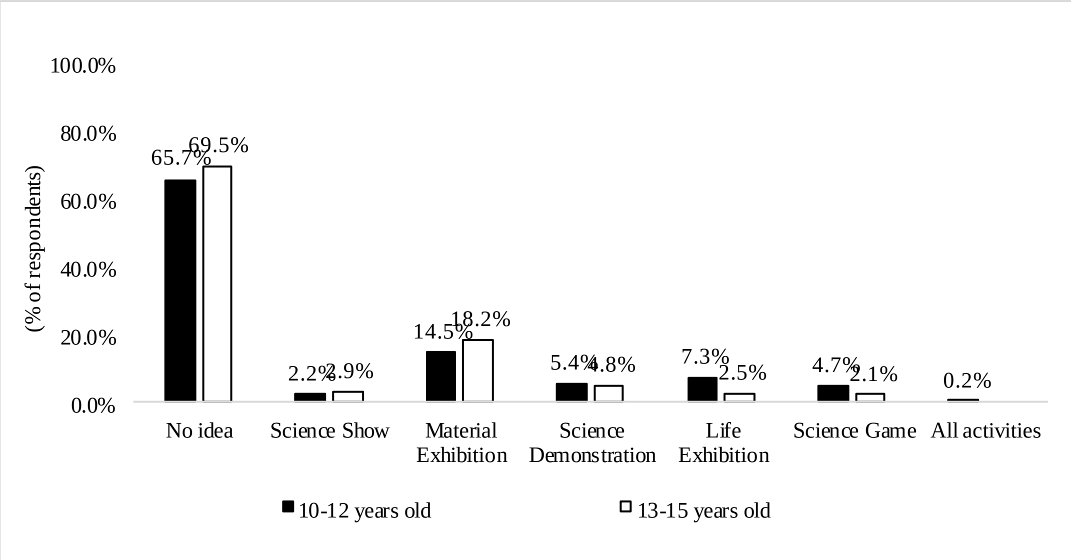
Figure 27: Least favourite activity of participants in each region



(3) Age

The Mann-Whitney U Test indicates differences in the data distribution between age groups in terms of the least favourite activity, with the *p-value* of 0.010 (<0.050) . Although both age groups indicated the Material Exhibit was their least favourite activity, this was higher amongst older participants (See Figure 28).

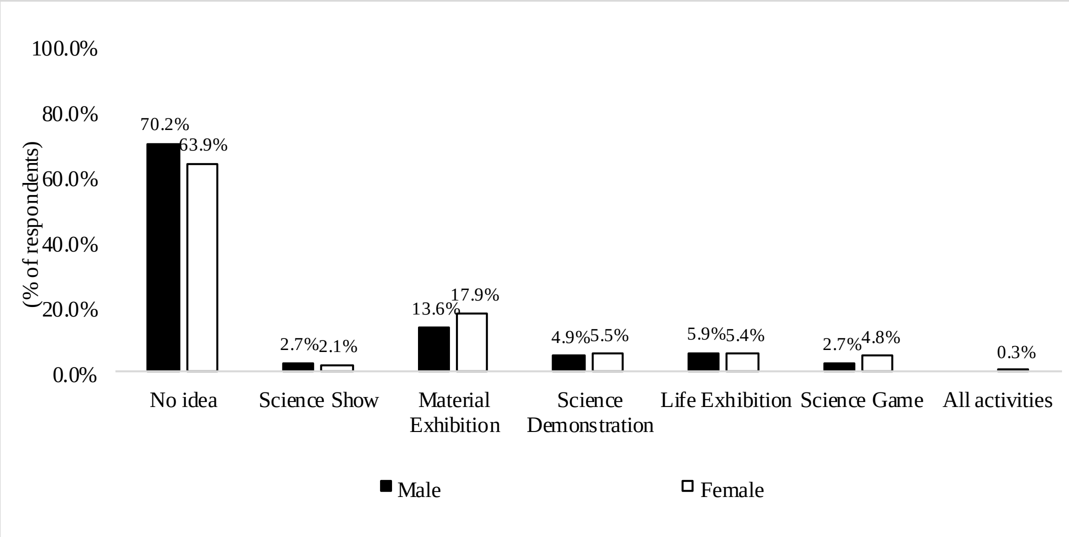
Figure 28: Least favourite activity of participants in different age groups (10–12 years old and 13–15 years old)



(4) Gender

In regards to gender in responding to their least favourite activities, the result from Mann-Whitney U Test were significantly different in regard to the data distribution between male and female participants, with the *p-value* of 0.022 (<0.050). A greater percentage of female participants indicated the Material Exhibition as their least favourite activity (see Figure 29).

Figure 29: Least favourite activity of male and female participants



7.3 Interview Results: Learning behaviours in the Science Caravan

In investigating how the informal science activities met the needs of participants a variety of learning behaviours were discussed in the student and NSM staff interviews which focussed on the interactions of participants within the Science Caravan activities. Learning behaviours were revealed from responses (N=57) in student interviews to questions which asked ‘What have you enjoyed about the Science Caravan?’ (N=38) and ‘Did you learn anything new? What was it?’ (N=19). Relevant results from NSM staff interviews were ascertained from their responses (N=12) to: ‘Which are the most popular activities and why?’ (N=7) and ‘What are the strengths of the caravan?’ (N=5). Five learning behaviours were identified: (1) watching and observing (N=18); (2) doing experiments/activities (N=38); (3) sharing knowledge and asking other people (N=5); (4) repeating the experiment/ activity (N=3); and (5) using experiences to solve the problem (N=5) (see Table 17).

Table 17: Learning behaviours of Science Caravan participants

Learning behaviours	Coding	Count (N=responses)				
		Student				NSM staff
		NE	N	C	S	
(1) Watching and observing	• Watched the explainer demonstrate a science experiment in the Science Show.	4	3	2	3	4
	• Observed the explainer perform the activities and tried to follow the demonstration.	1	-	-	-	1
(2) Performing experiments/ activities	Doing experiments/activities by themselves. For example, boys preferred to do experiments/activities themselves immediately, and primary school students liked making the chicken cup and playing with the chicken voice by themselves.	5	7	9	11	6
(3) Sharing knowledge and asking other people	• Helped students from another school to find an answer.	1	-	-	-	-
	• Worked with a team to find a science answer in a Science Game.	2	-	-	-	-
	• Asked the staff to help with the circuit.	-	2	-	-	-
(4) Repeating doing experiment/ activities	Repeated the balloon experiment again, which developed understanding of why the big balloon did not form in the plastic bottle the first time.	1	1	1	-	-
(5) Using experiences to solve the problem	Using experiences of learning in a classroom to participate in science activities in the Science Caravan.	1	2	1		1

Note: from Appendix D.4 (3) and D.6 (2); N: the North, NE: the Northeast, C: the Centre, S: the South

7.3.1 Watching/observing

Some participants (13 students and 5 NSM staff) identified watching or observing activities in the Science Caravan as a learning behaviour. In the Science Caravan, participants could observe other participants interacting with science activities, such as watching an explainer demonstrate experiments. Chowkeaw (an NSM female science communicator) explained that in her experience, observing others is the main method used by participants in exhibitions. They observe each other rather than asking questions because they are not always confident to approach the presenter or teacher (see Figure 30). In the student interviews, from four the Northeast participants, Nim (a female primary student from a host school of the Northeast) mentioned that the Science Show was her favourite activity because the demonstration was exciting and humorous. She said that the experiments the demonstrator presented helped her to clearly understand science phenomena such as air pressure and the occurrence of fog. Ponprapa (a female primary student from a host school of the North) referred to the science experiment involving air pressure.

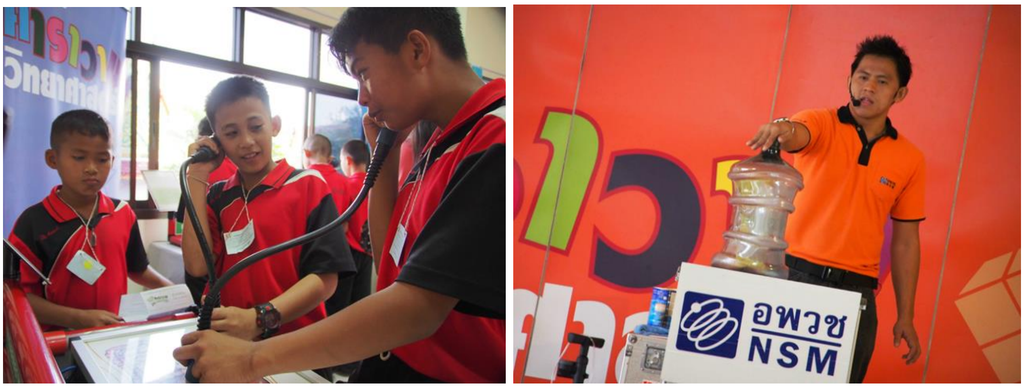
> I think observing the experiment helped me gain a better understanding of the principle of air pressure and its link with the school curriculum. I also better understood why the bottle contracted and sealed itself immediately after ethanol was burned in the bottle (see Figure 30). Moreover, the Science Show helped me gain more scientific knowledge rather than merely playing with the science exhibits on my own. At times it took too long to play with difficult exhibits in the material science room.

From the NSM staff's experience in the Science Caravan, Akkradach (a male science communicator of NSM) also mentioned that he observed participants in the different regions obtained knowledge from the Science Caravan engagement in different ways.

> In the Northeast participants, as we know, most Northeast participants have limits to learning performance such as reading and writing, these skills are also important to promote self-learning with science activities in the Science Caravan. Most of them observe their teacher interacting with exhibits and sometimes they observed other participants or explainers being engaged with

activities rather than interacting with activities directly themselves. Moreover, they lack confidence for asking others, sometime they found that it was difficult to ask others. Hence, their teachers need to help them learn and play with the exhibits and activities.

Figure 30: Observing as friends interact with the hands-on exhibits; Science Show: Air pressure and a squeezed bottle



7.3.2 Performing experiments/activities

Practicing or performing experiments by themselves was the most popular response among NSM interviewees (N=6) and student interviewees (N=32) regarding learning experiences they achieved or enjoyed. The majority of interview responses from the South participants (N=11) and follow by the Centre (N=9) indicated that they preferred learning through practising on they own. These participants mentioned that they liked to learn and solve problems by themselves such as engaging with the exhibits in the material and Life Exhibition rooms and making a chicken cup or completing the tangram on their own (see Figure 31).

Figure 31: The tangram and creativity; Science learning with the chicken cup

> I liked the Chicken Voice because I could create the chicken cup on my own and then learn how to make noise with the chicken cup. I also had to think about how to make the chicken crow the loudest. (Dream, a male primary school student from a guest school of the Centre)

> The tangram is my favourite activity. I liked putting seven flat shapes together to form a specific shape (given only an outline). It challenged my ability to put all seven pieces together on the outline without overlap. I liked to do it by myself. This activity helps me to develop my thinking and problem solving skills when thinking about how to include all pieces in many different outlines. (Wuttipong, a male primary school student from a host school of the South)

In the NSM interviews, Kraisak (a male science communicator of the NSM) stated that:

> From my experiences, I found that local participants they were willing to engage with science activities. However, there were some different learning behaviours that I found from my observation. I found that the South participants they quite pay attention to do these science activities. They enjoyed science experiments rather than watching the show. They also have more questions to the explainers or teachers about science activities. Moreover, they quite confident to discuss and express their ideas to others more than other regional participants. For the North and the Centre, they preferred to enjoy science games with challenging activities, and created the science toys by themselves. They also enjoyed fun science activities rather than taking it seriously as they would learning in school.

7.3.3 Asking and sharing knowledge and information with others

Asking and sharing knowledge with others was another learning behaviour which participants used to obtain knowledge from Science Caravan. This asking and sharing behaviour was identified by five student responses. The Northeast participant sometimes helped each other to complete activities, such as high school students helping younger participants make a chicken cup (N=1). Additionally, in the science activities room, some participants worked together as a team to play tangram, animal bingo and make a chicken cup. These games also encouraged the Northeast participants to develop social and communication skills (N=2). Moreover, asking the NSM staff for help completing activities was identified as a learning behaviour by two the North student responses.

> My most favourite activity was completing the electricity circuit. I liked this activity because it challenged me as she [the demonstrator] tried to complete the electric circuit. I tried to do it on my own, but I found that some circuits were too difficult, so I asked the NSM staff to explain and gave me some clues on how to complete the circuit.
>
> (Kingkeaw, a female high school student from a guest school of the Northeast)

Additionally, Baramee (a female primary school student from a guest school of the North) described her experience participating in the caravan. She said that she enjoyed all activities, made new friends from other schools, got involved with Science Games, and had a chance work with other students to do the tangram and compete with other groups. She confirmed that this activity helped her to make new friends from different schools and supported the development of her teamwork skills.

Therefore, asking and sharing knowledge was a learning behaviour that helped participants obtain more scientific knowledge and developed social and communication skills.

7.3.4 Repeating activities/experiments

Repeating activities were found in three responses from the Northeast, the North and the Centre students, and they mentioned that repeating activities helped participants obtain scientific knowledge and understanding. For example, Dream (a male primary school student from a guest school of the Centre) referred to his experiences in the material hands-on exhibitions room, specifying that he particularly liked the bicycle.

This exhibit explained the best material to use for the bicycle wheel. Wood, aluminium, steel and rubber were choices of materials from which to make a wheel. Dream attempted to find the best material by testing the friction of the materials. He tested these materials repeatedly until he was sure that rubber was the best material for the bicycle wheel. Moreover, Fame (a male primary school student from a host school of the Northeast) also mentioned that he repeated making a big balloon in the bottle. From repeating the experiment, he found that if the bottle had a hole, this opening would help him to achieve the big balloon in the bottle. When he attached the balloon, the air in the bottle was released through the hole, increasing the size of the balloon. Thus, repeating activities aids participants in gaining a better understanding of scientific knowledge.

7.3.5 Using experiences to complete experiments/activities

Learning experiences were credited as being useful to support participants in obtaining scientific knowledge from Science Caravan involvement. Hence, using experiences to support learning in the Science Caravan was a learning behaviour identified from four student responses (N=1 of the Northeast and the Centre, N=2 of the North) and one NSM staff response. Penpan (a female high school student from a host school of the North) stated that the Science Show encouraged her to think about why the plastic bottle was squeezed and sealed immediately after burning ethanol inside the bottle. She related the show to an experiment she had watched on YouTube. This experiment from YouTube helped her to gain a better understand about how the retracting of the bottle was linked with the air pressure principle. After the Science Show, she explained her ideas about air pressure to her friends and a teacher. She felt very confident in presenting, and her teacher accepted her answer.

Chapter summary

The results in this chapter address research question 3, *'How do informal science learning activities meet the needs of different demographic groups?'* by examining scientific knowledge change, activities that were liked by participants, and the learning behaviours that they identified using when participating in those activities.

The results show that participation in the Science Caravan promotes an increase in scientific knowledge for most participants, with post-test scores higher than the pre-test scores. The Northeast Science Caravan show having the most impact on post-test scores, though encouragingly there were no variations by age or gender. Science Games were the most popular activity amongst participants due to their variety and competitive elements, whereas the Material Exhibition was the least favourite science activity amongst respondents of the Northeast, the North and the Centre who perceived it to be challenging. Otherwise, the Science Show was the least favourite activity of the South respondents because it was noisy and seen to be dangerous, and participants lacked an opportunity to do the science experiments. However, there were minimal differences by region, age and gender.

The learning behaviours of participants interacting with science activities in Science Caravan were also examined and found to include examples of both individual learning (watching and observing activities, performing experiments, repeating activities and using experiences to solve the science problems) and social interaction (observing, discussion and sharing information with others). Most responses from the students interviews showed watching and observing people and activities, and performing experiment and activities, were the significant ways of learning that most young local people from the four regions used to obtain knowledge from caravan engagement. However, for the Southern participants, doing experiment activities by themselves was the important way of obtaining knowledge and understanding from the Science Caravan engagement, whereas the Northeast participants used to observe other and activities before they engaged with those activities. Additionally, asking and sharing was the significant way of learning that helped the Northeast participants learn science from their caravan involvement.

Chapter 8
Participation in Regional Informal Science Activities

Overview

This chapter addresses research question 4, '*What learning and other outcomes do young people obtain from participating in regional informal science activities?*' This chapter illustrates the results in three main sections. The first section presents the participants changing attitudes toward science and technology after participating in the Science Caravan and derived from the questionnaire results. The following section examines the learning outcomes identified in the questionnaire, as well as the interviews with young people and teachers. The final section illustrates participants' experiences of interacting with the Science Caravan, as well as limitations in engaging with the Science Caravan and the needs for future development.

8.1 Attitudes towards science and technology before and after participation

To explore how young people conceptualised science and formed attitudes towards it, ten questions (see Table 18) on the questionnaire were designed to identify attitudes towards science based on a 2008 survey of Science and Technology in Thailand by the National Science Technology and Innovation Policy Office (2008).

In this analysis, the attitudes toward science statements were examined by investigating the differences between the pre- and post-attitudes using the Wilcoxon Signed Ranks Test was used to examine the differences in the ways that the data was distributed. The results of the post-test were significantly different to the data distribution from those of the pre-test (the *p-value*< 0.050), participants changed their attitudes after participating in the Science Caravan.

Table 18: Attitudes towards science and technology questionnaire statements

No.	Statement of attitudes towards science and technology
1	Science and technology make our lives healthier, easier and more comfortable.
2	The application of science and technologies will make people's work more interesting.
3	We should follow up the advance of science and technology's news. Although, we will not be scientist.
4	Science and technology make our way of life change too fast.
5	Science and technology are relevant to everyday life.
6	People obtain great benefits from science and technology more than harmful effects.
7	Science and technology is important to our country's development.
8	Science and technology can sometimes damage people's moral sense.
9	Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.
10	Science and technology research should be supported by government because it brings on obvious immediate benefits.

Note: from Appendix A.4 and A.5

All attitudes apart from four and eight can be seen to be positive towards the role of science and technology within society, whilst agreement with attitude four and eight may show a degree of wariness. In exploring changing attitudes, there were four possible responses on the scale; strongly agree, agree, disagree and strongly disagree. Both the pre- and the post-test results were grouped: the agree group (included the number of *strongly agree* responses + number of *agree* responses) and the disagree group (number of *strongly disagree* responses + number of *disagree* responses).

In each test (the pre and the post-test), considering the different between numbers of responses in agree group and disagree group can tell about the direction of participant's perspective to these attitudes in more positive and negative.

A post-test result lower than the pre-test result meant that disagreement responses had increased. A post-test result higher than the pre-test result meant that the agreement responses had increased, and if the post-test result was equal to the pre-test result that meant the score in the post-test was not different from the pre-test.

This examination of changing attitudes toward science included consideration as to how participants' regions, age and gender affected any changes in participants' attitudes toward science.

8.1.1 All participants

In exploring the changing attitudes of all participants (N=1,400), the Wilcoxon Signed Ranks Test showed that eight attitudes have differences in the data distribution with *p*-value lower than 0.05, these were attitudes 1, 3, 4, 6, 7, 8, 9 and 10. Participants also changed their attitudes to these eight attitudes following engagement with the Science Caravan (see Appendix C.1).

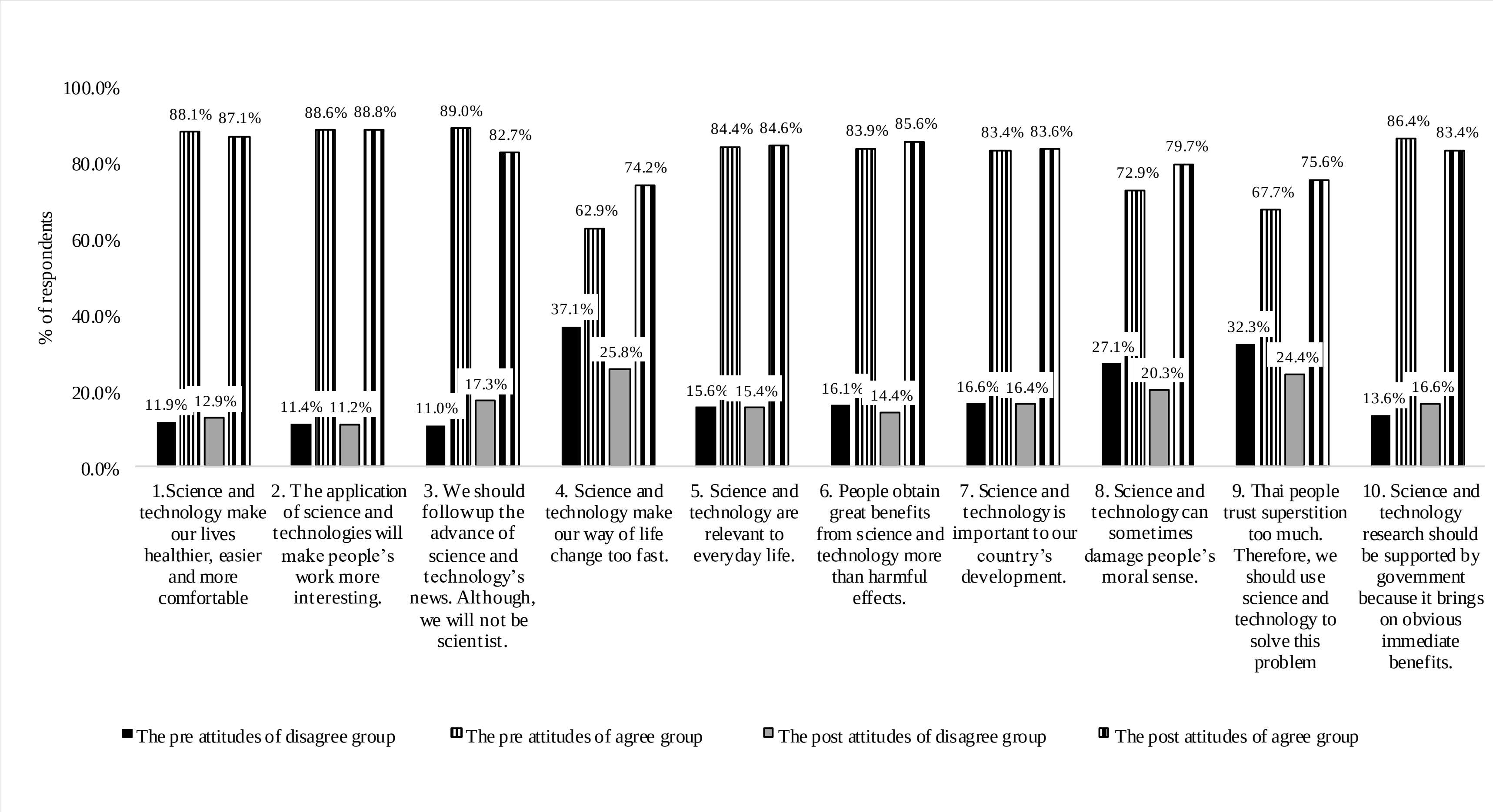
In terms of agreement participants were more likely to agree with attitude 6, 'People obtain more great benefits than harmful effects from science and technology'; attitude 7, 'Science and technology is important to our country's development'; and attitude 9, 'Thai people trust superstition too much. We should use science and technology to solve this problem' (see Figure 32 and Appendix C.2) following engagement with the caravan.

Moderately more participants disagreed that 'Science and technology make people lives healthier, easier and more comfortable', after engagement with the caravan, though there was still high levels of agreement overall at 87.1% (N=1,220) (see Appendix C.2). Likewise, the majority of post-test responses to attitude 3 and 10 were in the agree group, indicating that most participants still agreed that 'we should follow up the advance of science and technology's news. Although we will not be scientists' and 'science and technology research should be supported by government because it brings on obvious immediate benefits' but there was a small rise in the number of participants who disagreed with these attitudes statements.

In regards to attitudes 4 and 8; 'science and technology make the way of life change too fast', and 'science and technology can sometimes damage people's moral sense', there were also rises in agreement with these attitudes after participation in the caravan. There was an increase to 74.2% (N=1,039) from 62.9% (N=881) of agreement for attitude 4, and 79.7% (N=1,116) from 72.9% (N=1,020) in agreement with attitude 8 (see Figure 32 and Appendix C.2).

This shows a moderately mixed picture in regard to overall perceptions of the role of science and technology after engagement with the Science Caravan, but there remains high levels of positive attitudes in regard to science and technology overall.

Figure 32: Changing attitude towards science and technology of local young participants after engaged with the Science Caravan



8.1.2 Region

In examining changes in attitude towards science over the four geographical regions (N=350 for each region), the Kruskal Wallis Test was used to examine the data distribution of responses given in the pre and the post questionnaire to investigate the differences in attitude changes toward science between the Northeast, the North, the Centre and the South of Thailand. The results of the testing indicated the data distribution in the pre and the post questionnaire to the ten attitudes of four regions are significantly different, with *p-value* lower than 0.05 of Kruskal Wallis Test, Table 19 provides a summary of these results.

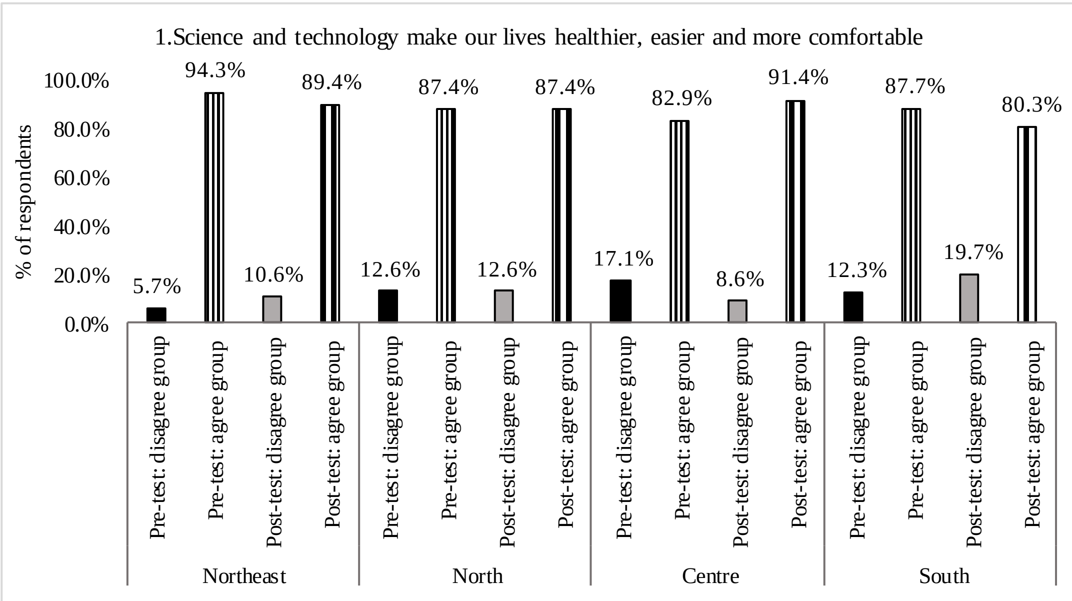
Table 19: Examining changing attitudes toward science and technology in the four regions

Attitudes toward science and technology	Northeast (N=350)	North (N=350)	Centre (N=350)	South (N=350)
1. Science and technology make our lives healthier, easier and more comfortable.	-	=	+	-
2. The application of science and technology will make people's work more interesting.	-	+	+	-
3. We should follow news on the advances of science and technology even though we will not be scientists.	-	-	-	+
4. Science and technology make our way of life change too fast.	-	+	+	+
5. Science and technology are relevant to everyday life.	+	-	+	-
6. People obtain more great benefits than harmful effects from science and technology.	+	-	-	+
7. Science and technology is important to our country's development.	+	-	+	-
8. Science and technology can sometimes damage people's moral sense.	+	+	+	-
9. Thai people trust superstition too much. We should use science and technology to solve this problem.	+	+	-	+
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	+	-	-	-

Note: (1) - : the difference in the agreement and disagreement of the post-test < the difference in the agreement and disagreement of the pre-test, (2) +: the difference in the agreement and disagreement of the post-test > the difference in the agreement and disagreement of the pre-test, (3) =: the difference in the agreement and disagreement of the post-test = the difference in the agreement and disagreement of the pre-test (see Appendix C.3 to C.6).

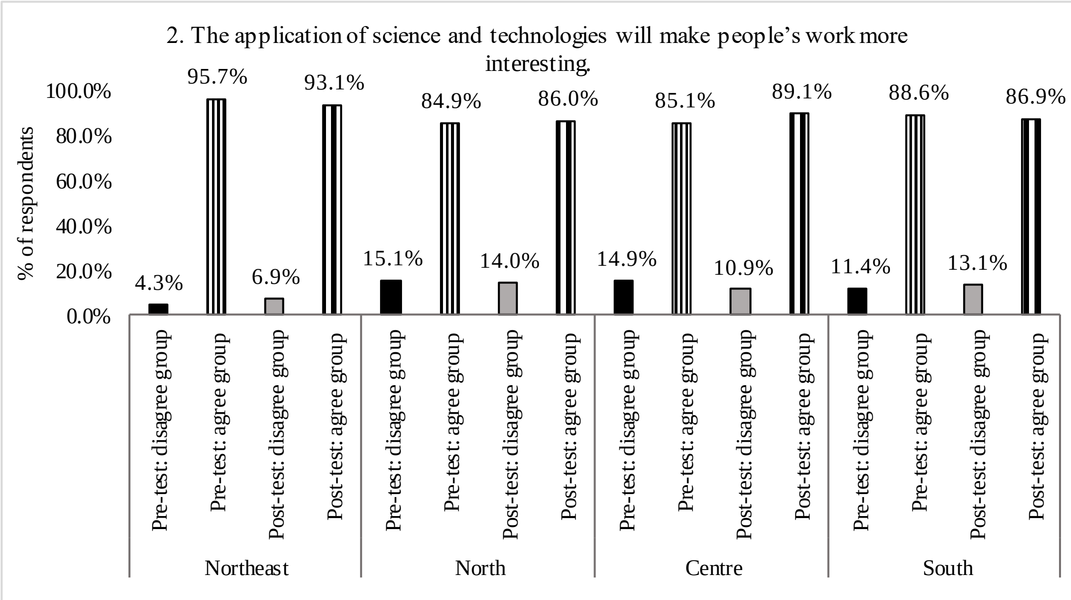
In relation to attitude 1, most central and northern participants have positive attitudes that 'Science and technology make our lives healthier, easier and more comfortable' both before and after participation. Whereas the northeast and the southern participants showed small rises in numbers of participants who disagreed with this attitude after participation (see Figure 33 and Table 19).

Figure 33: Attitude 1 Regional Differences



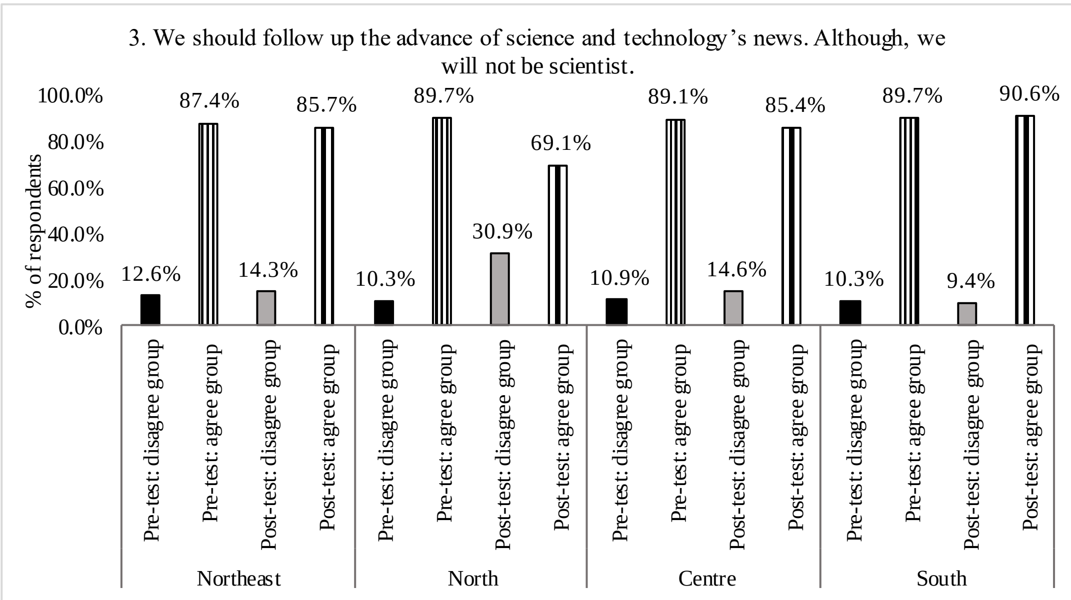
In regard to attitude 2, most participants from the four regions showed agreement with this statement, with rising agreement amongst northern and central participants, whilst the Northeast and the South showed small rises in those disagreeing with this statement (see Figure 34 and Table 19).

Figure 34: Attitude 2 Regional Differences



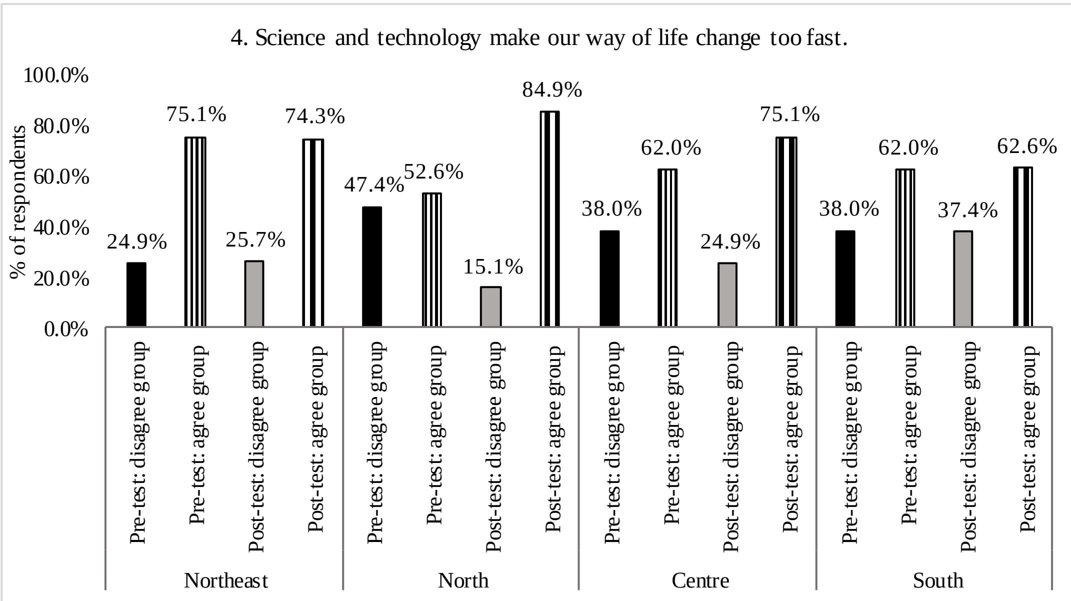
In terms of attitude 3, most participants agreed 'we should follow news on the advances of science and technology even though we will not be scientists' with increases in agreement in the South after participation. However in all three other regions, some participants from the Northeast, the North and the Central came to disagree with this statement after engaging with the caravan (see Figure 35 and Table 19).

Figure 35: Attitude 3 Regional Differences



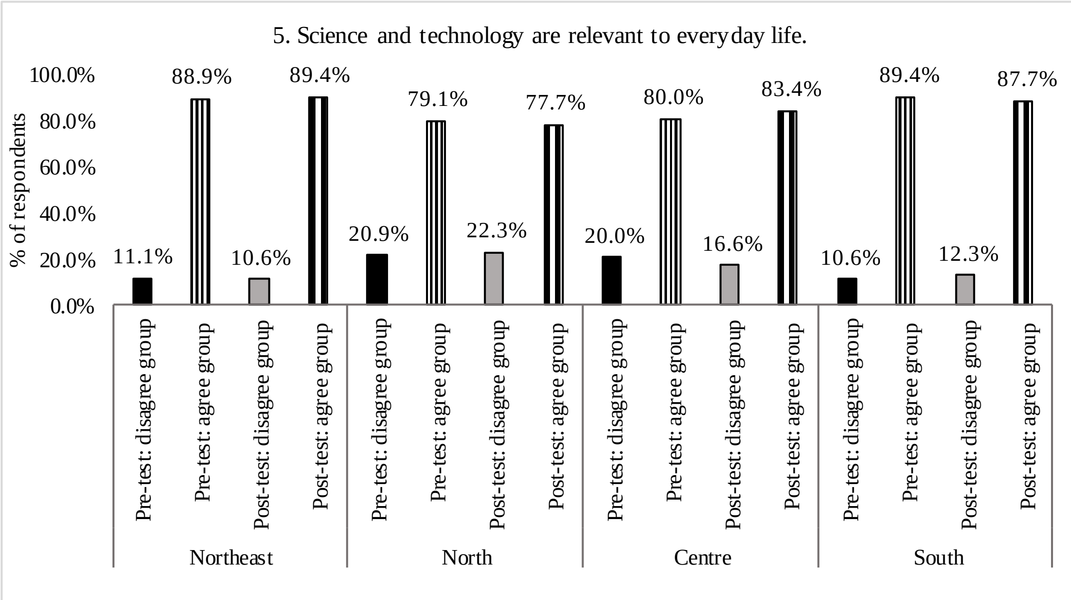
For attitude 4, there was a reasonably high level of agreement amongst participants that 'science and technology make our way of life change too fast', with the northeast participants showing the only rise in people disagreeing with this statement. In the North, the number of participants who came to agree with this statement was noticeably higher than other three regions. More northern participants came to agree with this attitude at 84.9% (N=297) from 52.6% (N=184) (see Appendix C.4) after caravan engagement, while in the Centre and the South, a more moderate increase was recorded (see Figure 36 and Table 19).

Figure 36: Attitude 4 Regional Differences



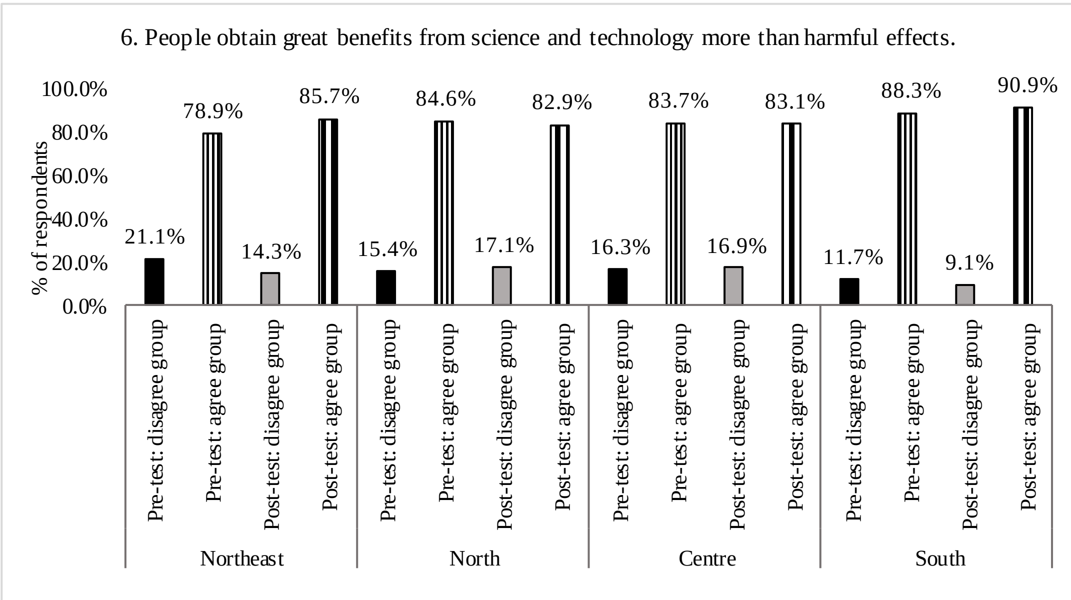
In relation to attitude 5, 'Science and technology are relevant to everyday life. There were increases in northeast and central participants agreeing with these attitudes, whereas small numbers of northern and southern participants shifted to 'disagree' (see Figure 37 and Table 19).

Figure 37: Attitude 5 Regional Differences



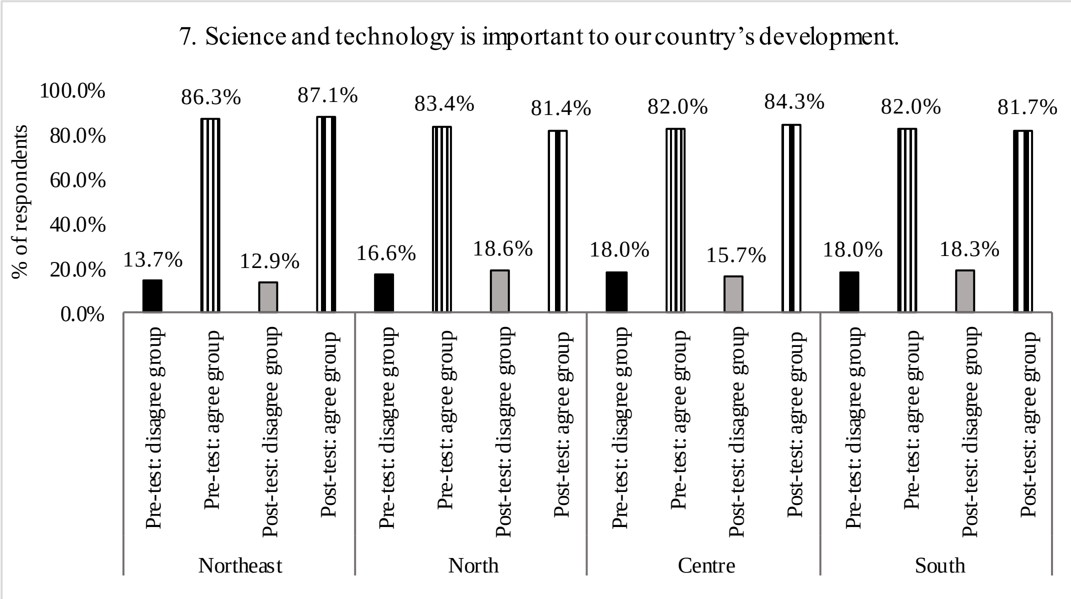
In terms of attitude 6, 'People obtain more great benefits than harmful effects from science and technology', northeast and southern participants showed some additional agreement these attitude statements, whereas some northern and central participants disagreed after engagement (see Figure 38 and Table 19).

Figure 38: Attitude 6 Regional Differences



In relation to attitude 7, 'Science and technology is important to our country's development', most northeast and central participants changed to agreeing with these attitudes, whereas some northern and southern participants shifted to ‘disagree’ (see Figure 39 and Table 19).

Figure 39: Attitude 7 Regional Differences



Finally, in terms of attitude 8, ‘science and technology can sometimes damage people’s moral sense’ only participants in the South saw a rise in disagreement with this statement with all other regions showing small increases in agreement. While for attitude statement 9, ‘Thai people trust superstition too much. We should use science and technology to solve this problem’ there were increases in agreement with this statement for all regions apart from the Centre. Attitude 10, ‘science and technology research should be supported by government because it brings on obvious immediate benefits’, showed a rise of agreement only in the Northeast region (see Figure 40 to 42 and Table 19).

Figure 40: Attitude 8 Regional Differences

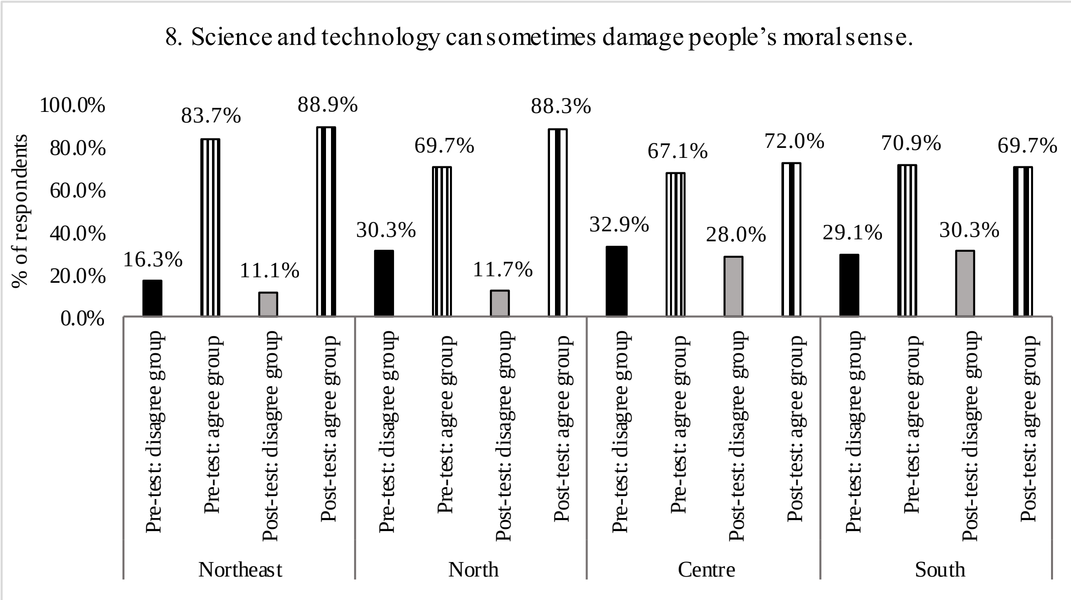


Figure 41: Attitude 9 Regional Differences

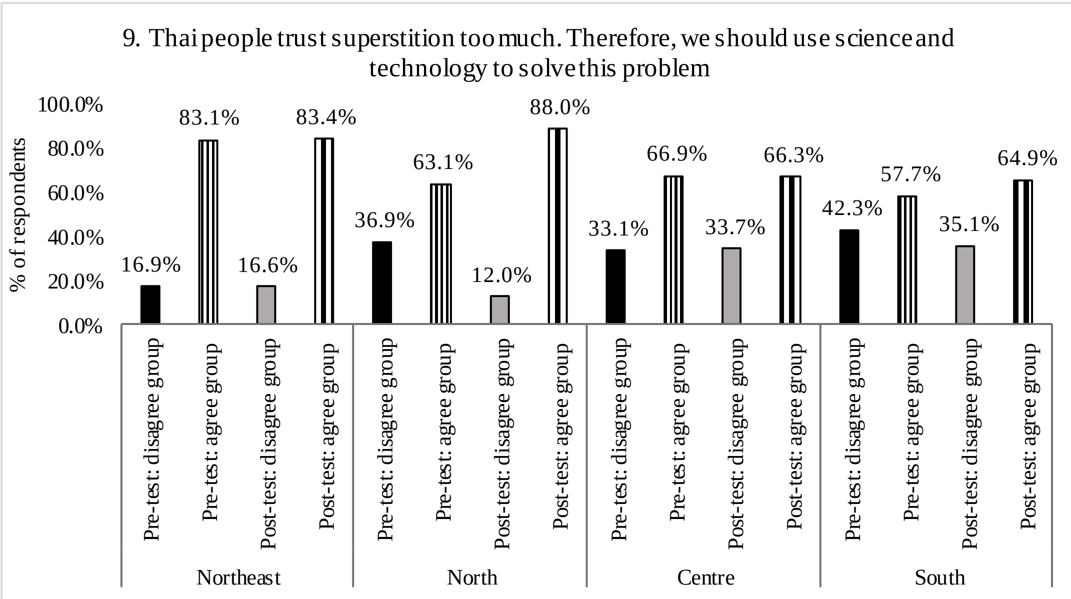
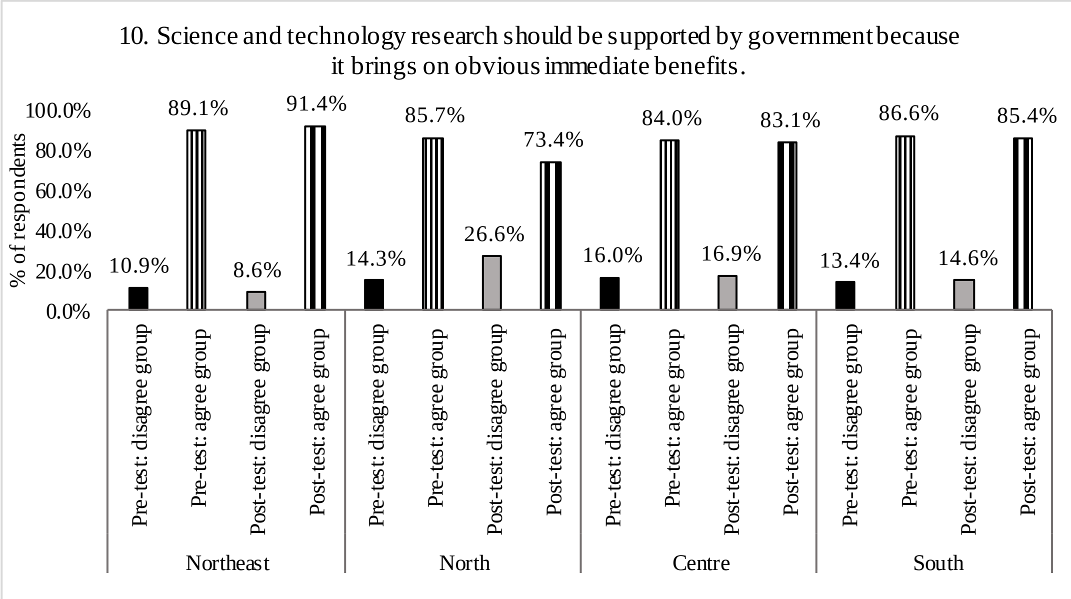


Figure 42: Attitude 10 Regional Differences



In summary, at the regional level there were no clear trends in regard to agreement or disagreement with the attitude statements after participation, with changes that could be seen as positive and negative in regard to overall attitudes to science and technology seen across all four regions.

8.1.3 Age

In investigating the differences in attitude change between both age groups (10–12 years old (N=922) and 13–15 years old (N=478)), differences in the data distribution of responses in the pre- and the post-test questions were tested via a Mann Whitney U Test, the results illustrated that the *p-value* of all ten attitudes had above 0.05 significance level. The changing attitudes toward science between both age groups were not significantly different amongst the two age groups.

However, exploring the difference in the agreement and disagreement of the pre- and the post-test attitudes shows some general trends in the statements where a rise in agreement was seen amongst both age groups (see Table 20).

Table 20: Examining changing attitudes toward science of participants in different age groups (10–12 years old and 13–15 years old)

Attitudes toward science and technology	10–12 years old (N=922)	13–15 years old (N=478)
1. Science and technology make our lives healthier, easier and more comfortable.	-	-
2. The application of science and technologies will make people's work more interesting.	-	-
3. We should follow news on the advances of science and technology even though we will not be scientists.	-	-
4. Science and technology make our way of life change too fast.	+	+
5. Science and technology are relevant to everyday life	-	-
6. People obtain more great benefits than harmful effects from science and technology.	-	-
7. Science and technology is important to our country's development.	-	-
8. Science and technology can sometimes damage people's moral sense.	+	+
9. Thai people trust superstition too much. We should use science and technology to solve this problem.	-	-
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	-	-

Note: (1) - : the difference in the agreement and disagreement of the post-test < the difference in the agreement and disagreement of the pre-test, (2) +: the difference in the agreement and disagreement of the post-test > the difference in the agreement and disagreement of the pre-test, (3) =: the difference in the agreement and disagreement of the post-test = the difference in the agreement and disagreement of the pre-test (see Appendix C.7 and C.8).

From Table 20, we can see that participants of both of age groups showed increases in their agreement with attitude 4, 'science and technology make our way of life change too fast' (an increase of just over 14.1% for 10-12 year olds and 5.8% for 13-15 year olds) and attitude 8, 'Science and technology can sometimes damage people's moral sense' (an increase of just under 7.6% for 10-12 year olds and 5.5% for 13-15 year olds). For all other attitude statements, most participants of both groups are still in agreement with these statements (attitudes 1, 2, 3, 5, 6, 7, 9 and 10), but some participants came to disagree with them (see Table 20, Figure 43 and Figure 44).

Figure 43: Changing attitudes toward science and technology of participant's age 10-12 years old

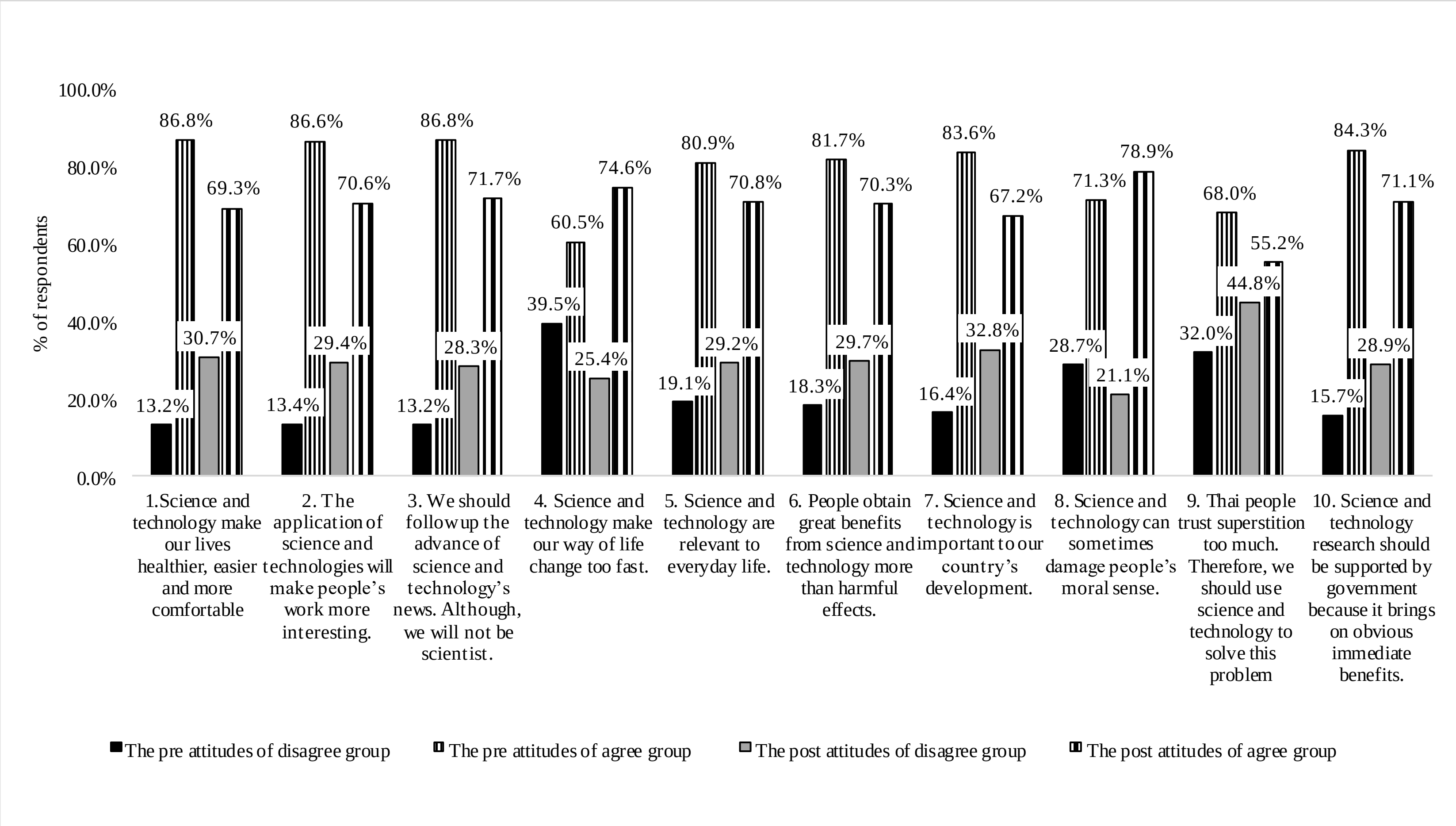
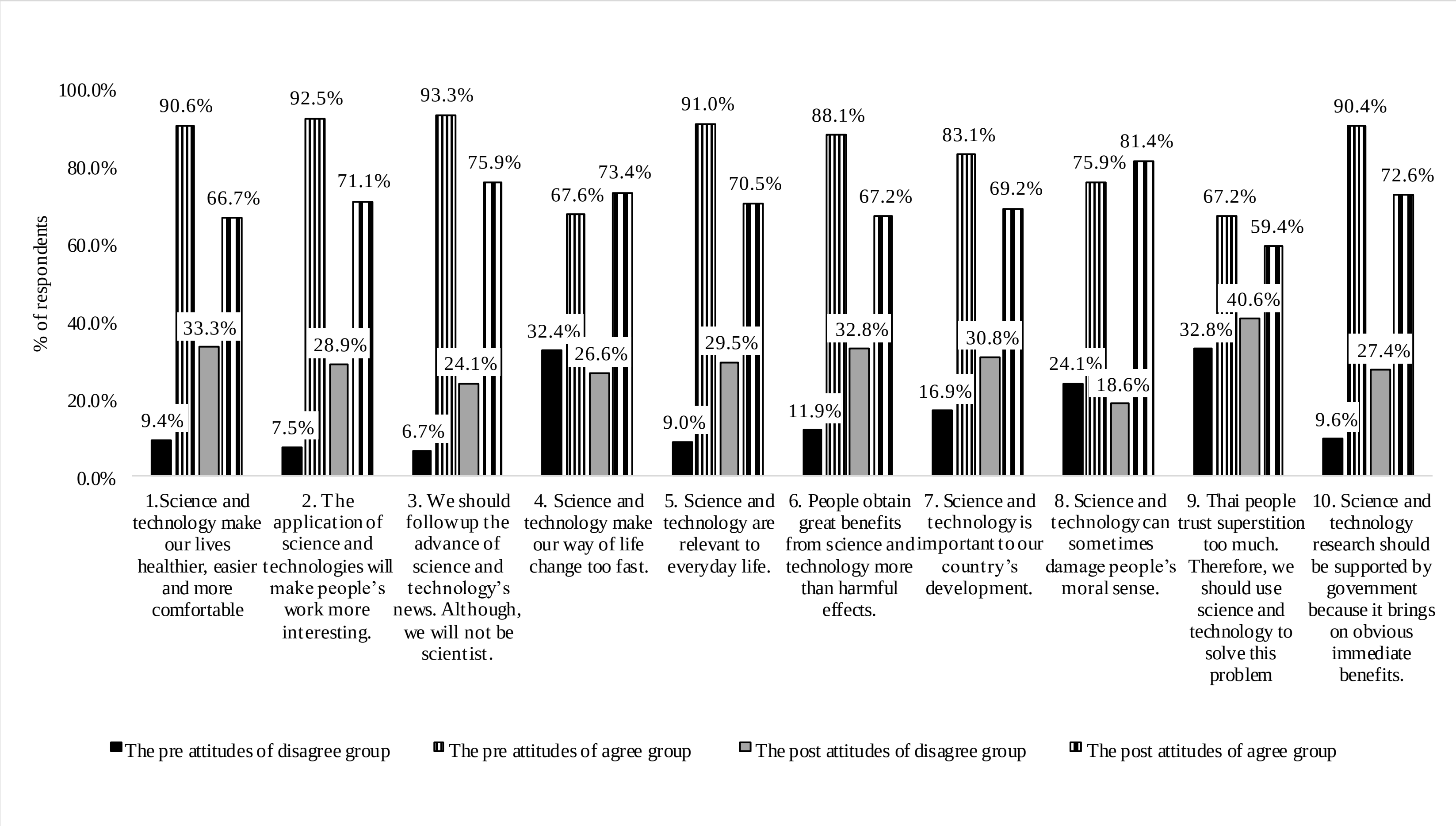


Figure 44: Changing attitudes toward science and technology of participant's age 13-15 years old



8.1.4 Gender

In studying the differences in attitude change amongst male and female participants, a Mann Whitney U Test was used to examine the differences in data distribution of the responses in the post-test and the pre-test attitudes between both gender groups. The testing results illustrated that the *p-value* of testing all of ten attitudes had a higher than 0.05 of significance level. The changing attitudes towards science between both gender groups was not therefore different. However, exploring the differences in the agreement and disagreement of the pre-test and the post-test changes in Table 21 showed some moderate differences in the changing attitudes toward science and technology of both gender groups.

Table 21: Examining changing attitudes toward science of male and female participants.

Attitudes toward science and technology	Male (N=697)	Female (N=703)
1. Science and technology make our lives healthier, easier and more comfortable.	-	-
2. The application of science and technologies will make people's work more interesting.	+	-
3. We should follow news on the advances of science and technology even though we will not be scientists.	-	-
4. Science and technology make our way of life change too fast.	+	+
5. Science and technology are relevant to everyday life	-	+
6. People obtain more great benefits than harmful effects from science and technology.	+	-
7. Science and technology is important to our country's development.	+	-
8. Science and technology can sometimes damage people's moral sense	+	+
9. Thai people trust superstition too much. We should use science and technology to solve this problem.	+	+
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	-	-

Note: (1) - : the difference in the agreement and disagreement of the post-test < the difference in the agreement and disagreement of the pre-test, (2) +: the difference in the agreement and disagreement of the post-test > the difference in the agreement and disagreement of the pre-test, (3) =: the difference in the agreement and disagreement of the post-test = the difference in the agreement and disagreement of the pre-test (see Appendix C.9 and C.10).

From Table 21, the results show variation in attitude towards science and technology between male and female participants in regards to attitudes 2, 5, 6 and 7. More male participants came to agree with attitude 2 ‘The application of science and technology will make people’s work more interesting’, 6 ‘People obtain great benefits from science and technology more than harmful benefits’, and 7 ‘Science and technology is important to our countries development’, whereas some female participants switched to disagreeing with these attitudes. For female participants attitude 5 showed a positive change, more female participants came to agree with the statement ‘science and technology are relevant to everyday life’, whilst some male participants changed to disagree with this attitude statement (see Figure 45 and Figure 46).

Figure 45: Changing attitudes toward science of male participants.

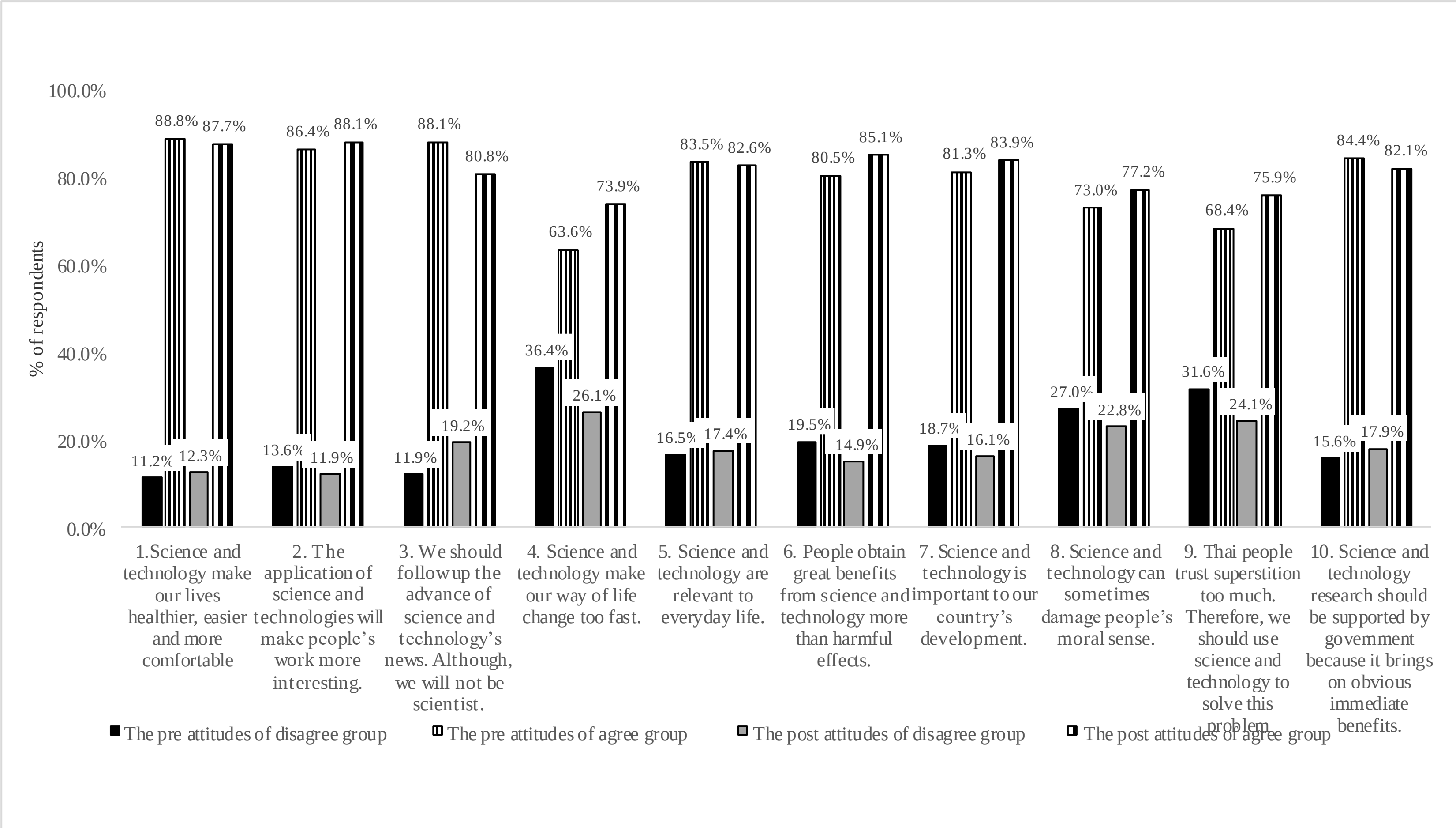
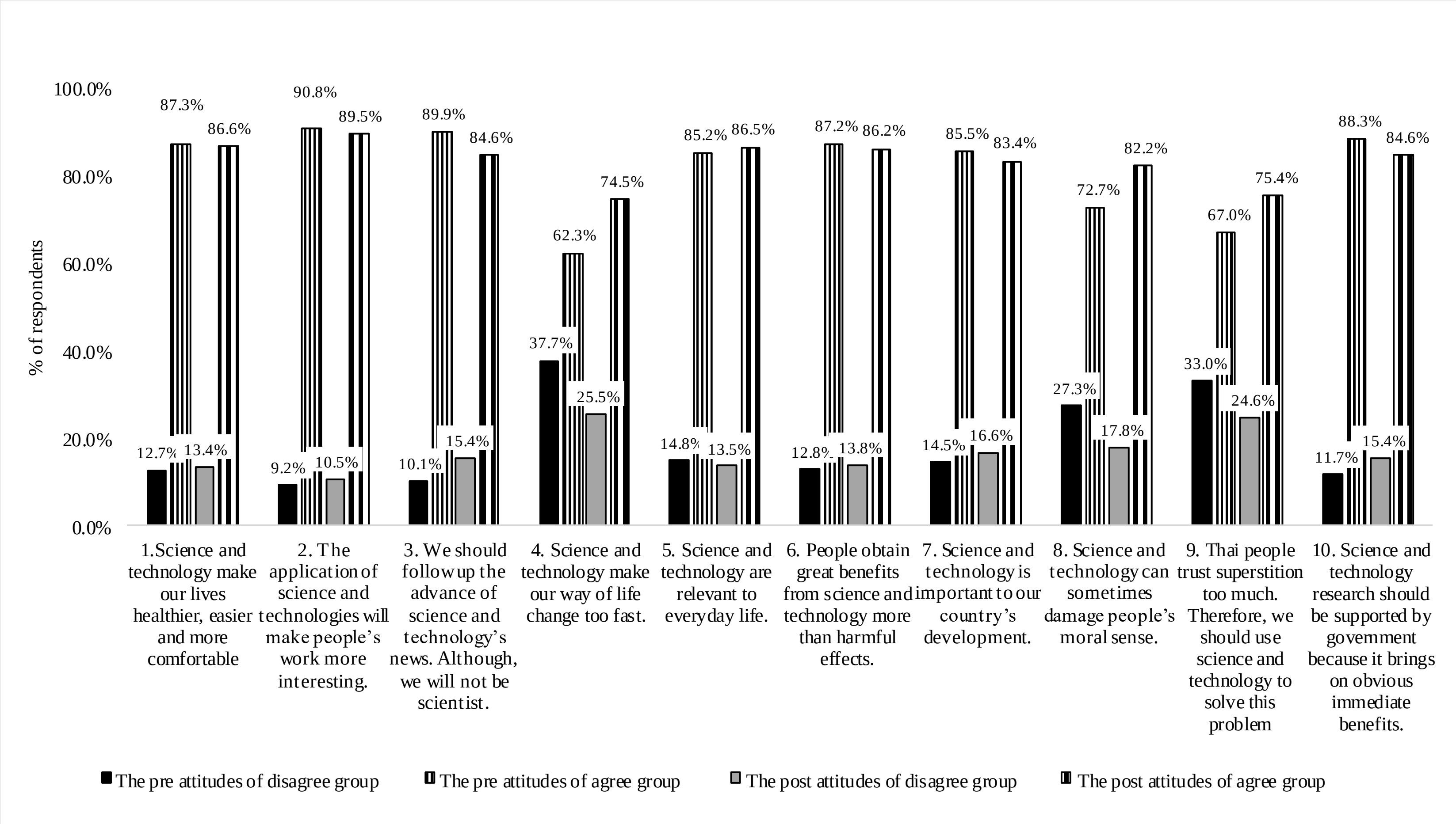


Figure 46: Changing attitudes toward science of female participants.



8.2 Learning outcomes from participation

This section explores the post questionnaire and the interview results to examine the learning outcomes that participants obtained or perceived after engaging with the Science Caravan.

8.2.1 Learning outcomes

The questionnaire asked participants to detail what they had obtained from the science activities. Participants provided this information in response to the ten questions in the post-questionnaire section on learning outcomes (see Appendix A.5). These questions were developed from Punyain's (2008) constructivist learning environment survey, a questionnaire that was used to explore the learning outcomes of young visitors to the Chiang Mai Zoo. To incorporate the context of an informal environment, the Generic Learning Outcomes (GLOs) were also used to frame the post-questionnaire questions based on five learning categories (see Chapter 4, in section 4.5.2). In exploring learning outcomes of young participants, there were four options provided on the scale for responding; strongly agree, agree, disagree and strongly disagree.

In the data analysis, the percentages of respondents in the *agree* groups (agree and strongly agree) and *disagree* groups (disagree and strongly disagree) were used to explore participant learning outcomes. If the percentage of the agree group was higher than the disagree group this meant participants agreed that they obtained this outcome from participating in the caravan. If the percentage of the agree group was lower than disagree group this meant participants disagreed that they had obtained this outcome from participating in the caravan.

This technique was applied from Art Council England's (2016) method for recording and analysing quantitative data concerning the Generic Learning Outcomes (GLOs).

(1) All participants

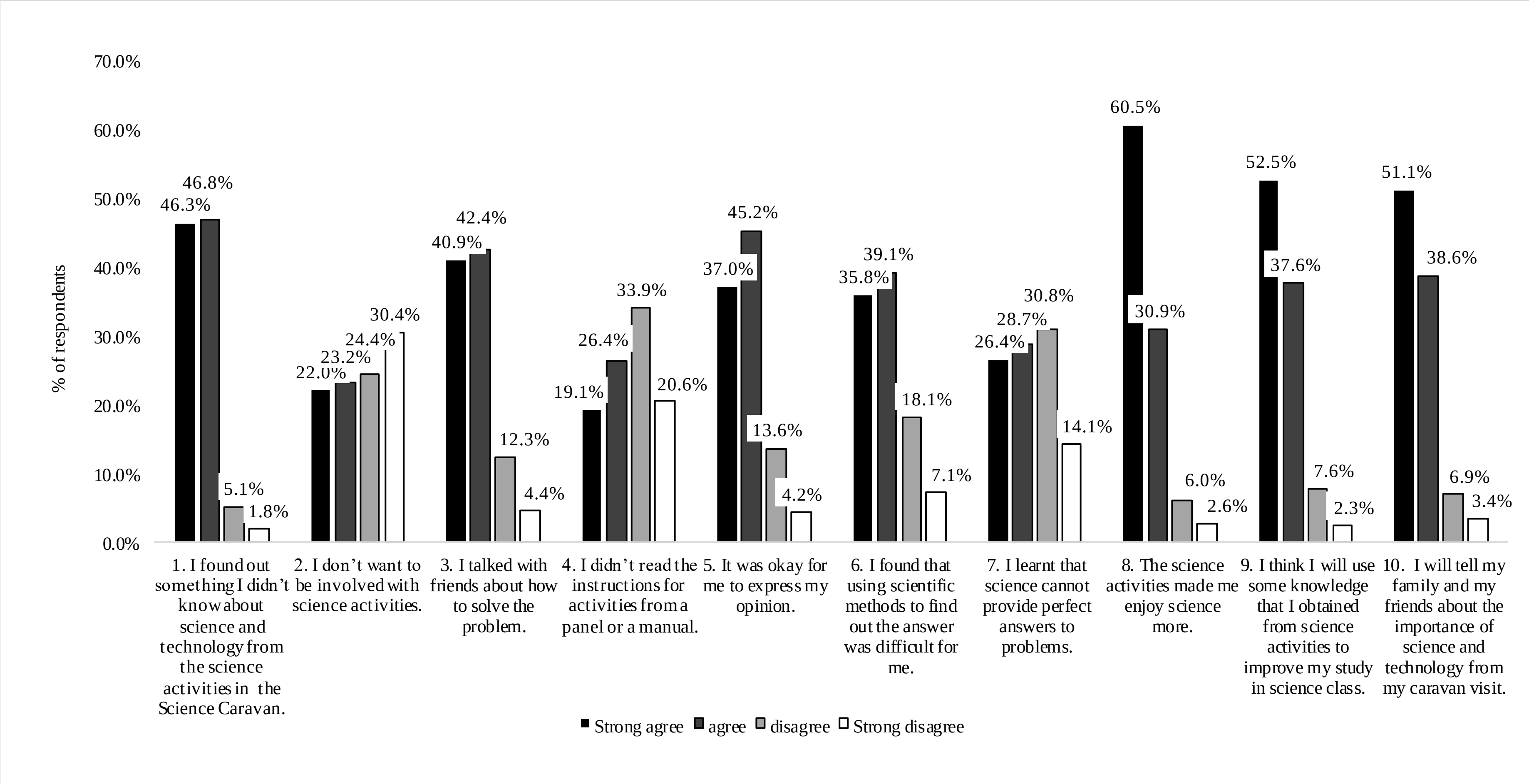
Exploration of the 1,400 participants provided an overall picture of the learning outcomes in the four regions. Most participants were in agreement that learning outcomes had been met.

Figure 47 shows the levels of agreement (agree and strongly agree) for all learning outcomes. 93.1% (N=1,304) agreed ‘I found out something I didn’t know about science and technology from the science activities in Science Caravan’ (see Appendix C.11). Over 80% also agreed that ‘The science activities made me enjoy science more’ and ‘I think I will use some knowledge that I obtained from science activities to improve my study in science class’. This evidence demonstrates that participants obtained new knowledge of science and technology. They also enjoyed science more after participating in the caravan and that that they think the caravan visit will be helpful in promoting the improvement of science learning in the classroom.

However, participants were also challenged by the activities, learning outcome 6, ‘I found that using scientific methods to find out the answer was difficult for me’ saw 74.9% (N=1,048) agreement (see Appendix C.11). Learning outcome 7 also suggested an awareness of the challenges of the scientific method, ‘I learnt that science cannot provide perfect answers to problems’ saw 55.1% (N=771) participants in agreement.

Figure 47 illustrates that two learning outcomes also saw a more mixed response. Learning outcome 2, ‘I don’t want to be involved with science activities’, had 45.2% (N=633) in the agree group (see Appendix C.11). The results suggested that most of the young people did want to be involved with science activities. Learning outcome 4, ‘I didn’t read the instructions for activities from a panel or a manual’, also had a higher percentage in the disagree group, at 54.5% (N=763), suggesting most students were following the instructions for activities (see Appendix C.11).

Figure 47: Learning outcomes of the Science Caravan amongst all participants

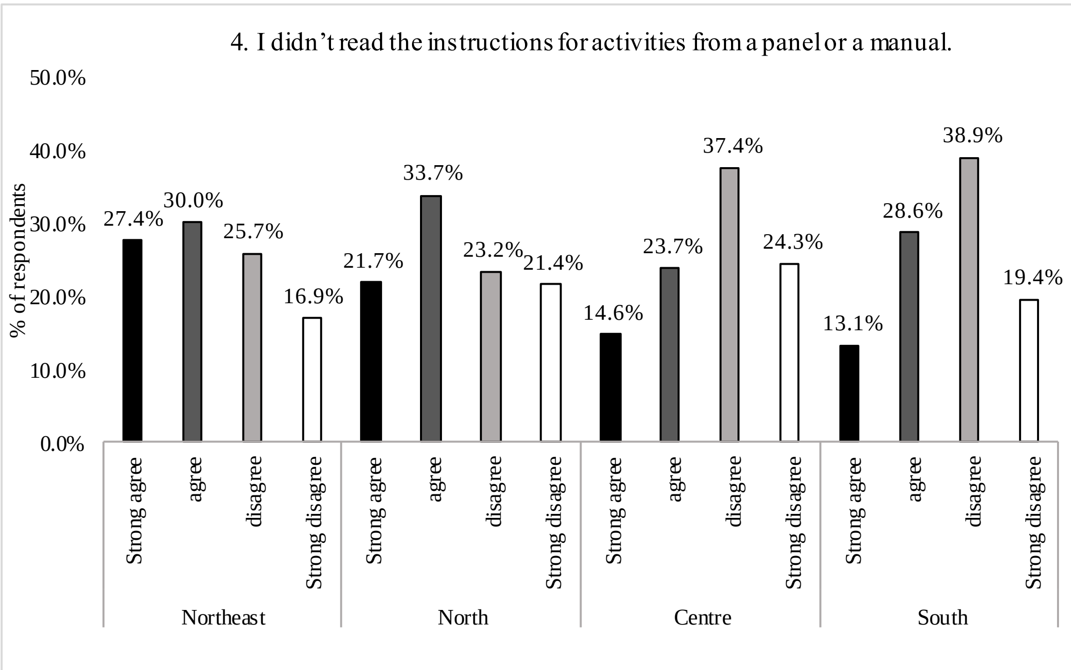


(2) Region

The Kruskal Wallis Test was used to investigate the differences in data distribution in the learning outcomes between the Northeast, the North, the Centre and the Southern participants. The results of the test indicated significant differences of the data distribution, with the *p-value* lower than 0.05 in learning outcomes 1, 4, 5, 6, 7, 8, 9 and 10. From the result, learning outcomes 4 and 7 had the greatest varying percentages of agreement and disagreement at a regional level.

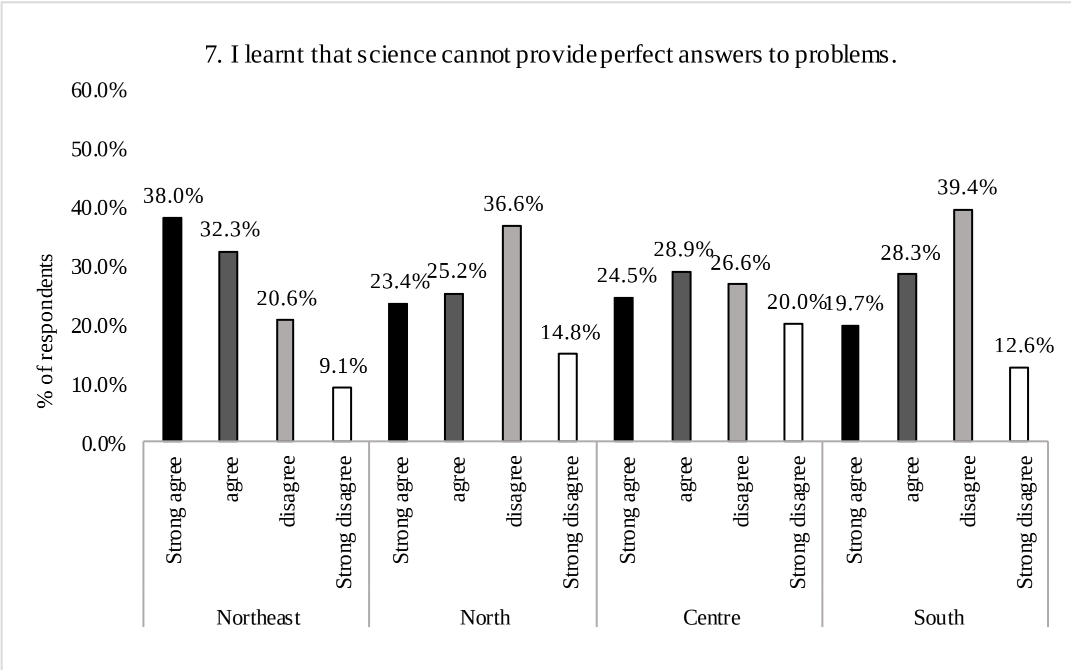
In learning outcome 4 ‘I didn’t read the instructions for the activities from a panel or a manual’, the majority of northeast and northern participants strongly agreed and agreed with this outcome at 57.4% (N=201) and 55.4% (N=194), respectively (see Appendix C.12 and C.13). The results suggested that these two regional groups did not read the activities instructions, whereas the southern and central participants were more likely to say that they did when they interacted with the activities. The results showed the central and southern participants strong disagreed and disagreed with this statement, at 61.7% (N=216) and 58.3% (N=204), respectively (see Figure 48 Appendix C.14 and C.15).

Figure 48: Learning outcome 4 Regional Differences



For learning outcome 7 ‘I learnt that science cannot provide perfect answer to problems’, the northern and the southern participants largely disagreed with 51.4% (N=180) and 52.0% (N=182) disagreeing with that statement (see Appendix C.13 and C.15). Alternatively, the northeast and central participants were more likely to agree with this statement after interacting (see Appendix C.12 and C.14) (see Figure 49).

Figure 49: Learning outcome 7 Regional Differences



For learning outcome 1, 5, 6, 8, 9 and 10 levels of agreement amongst participants in the regions was largely the same, but the strength of agreement or disagreement and therefore the number of people in the strongly agree/disagree categories varied slightly (see Figure 50 to Figure 55 And Appendix C.12 to C.15).

Figure 50: Learning outcome 1 Regional Differences

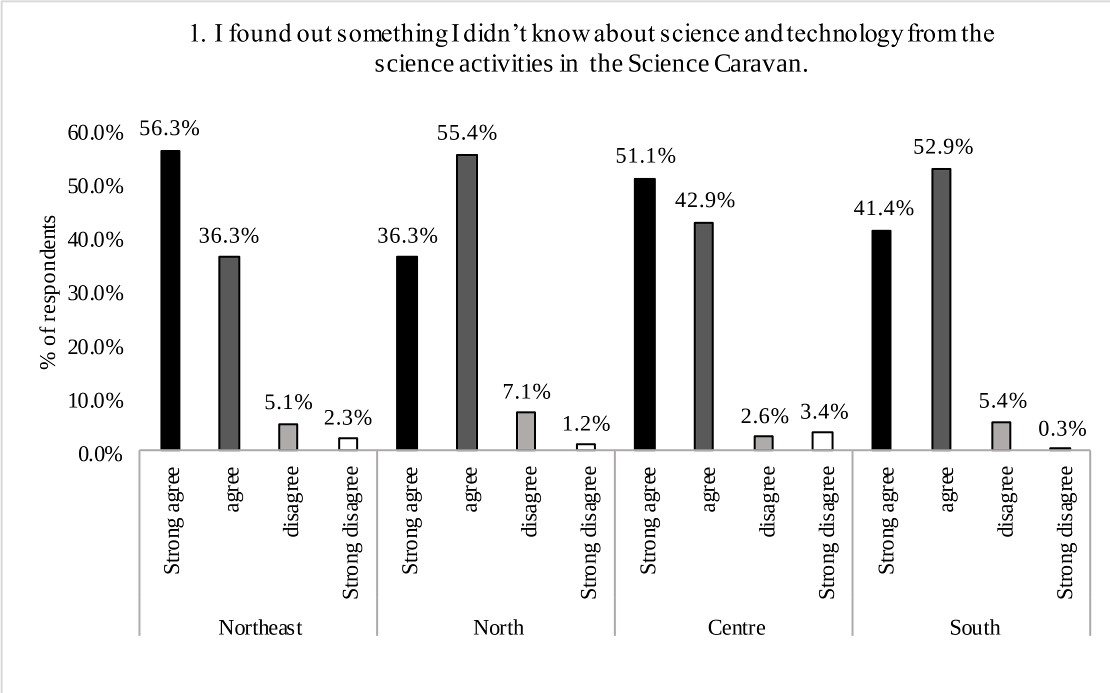


Figure 51: Learning outcome 5 Regional Differences

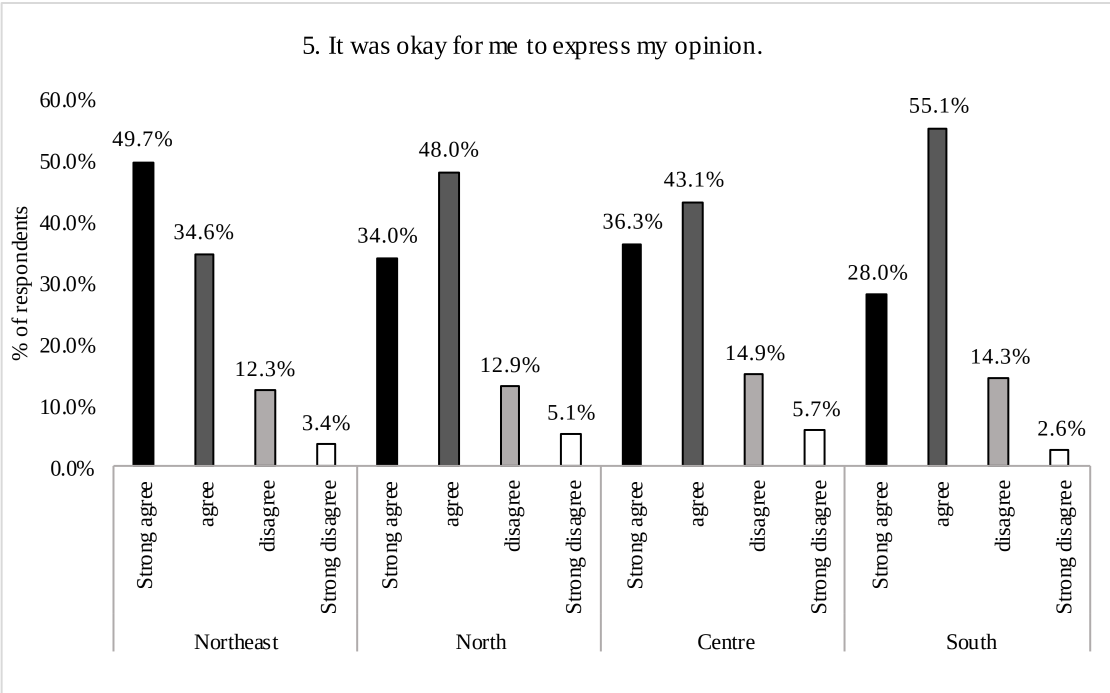


Figure 52: Learning outcome 6 Regional Differences

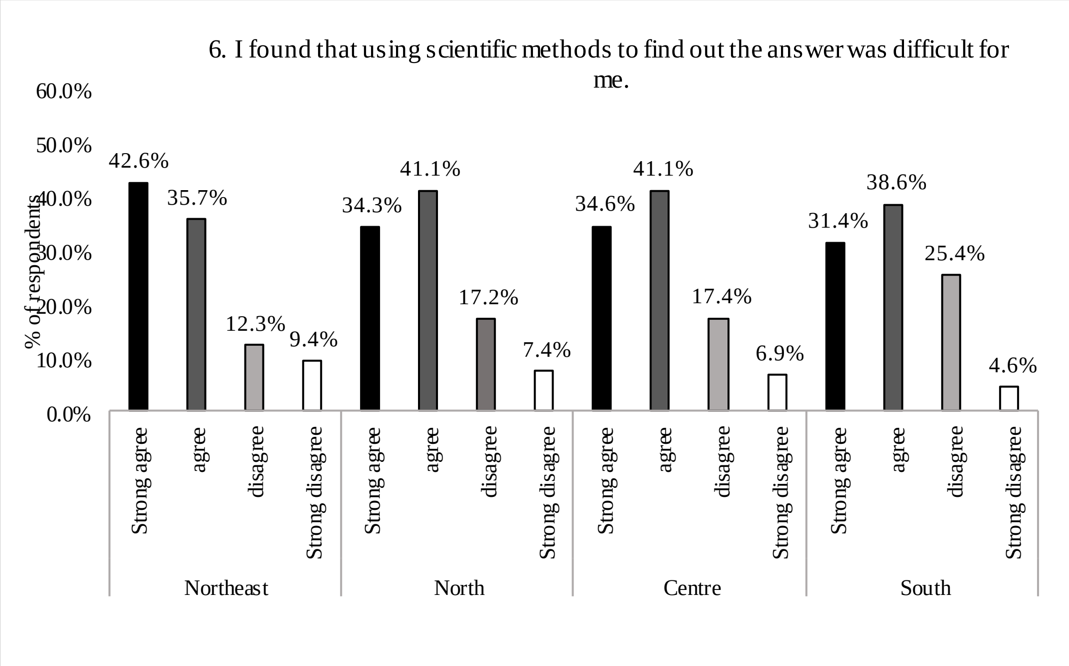


Figure 53: Learning outcome 8 Regional Differences

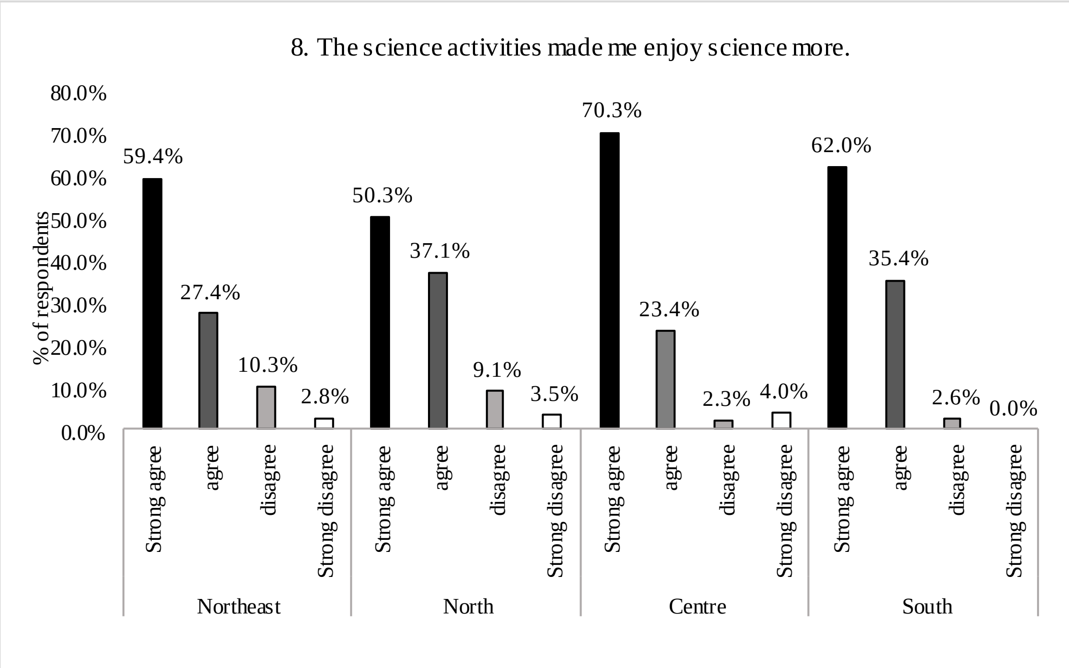


Figure 54: Learning outcome 9 Regional Differences

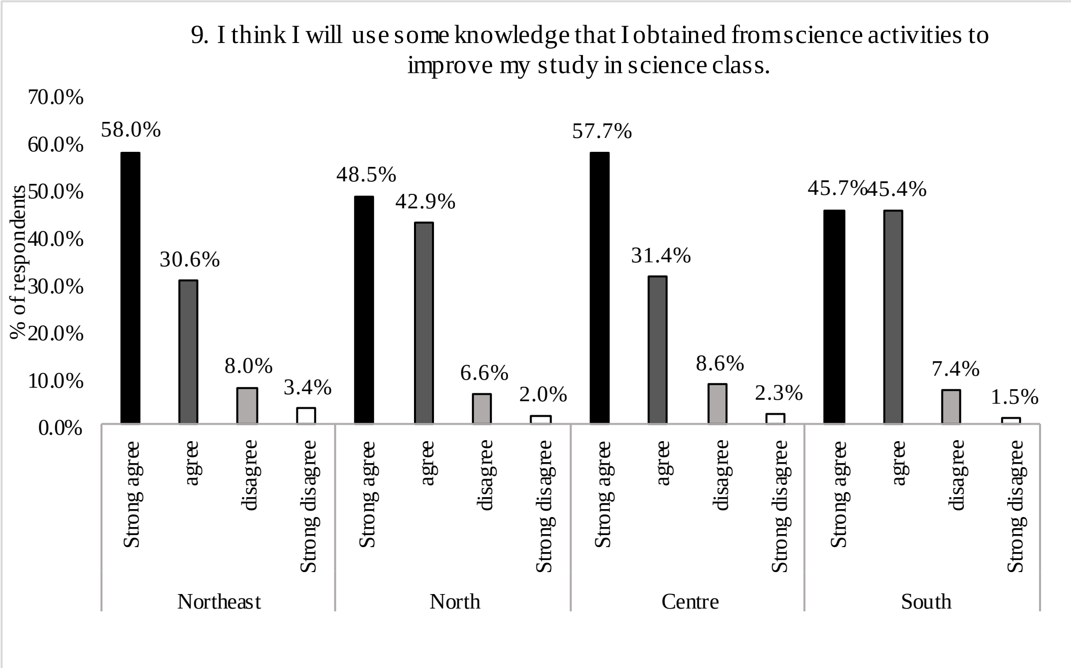
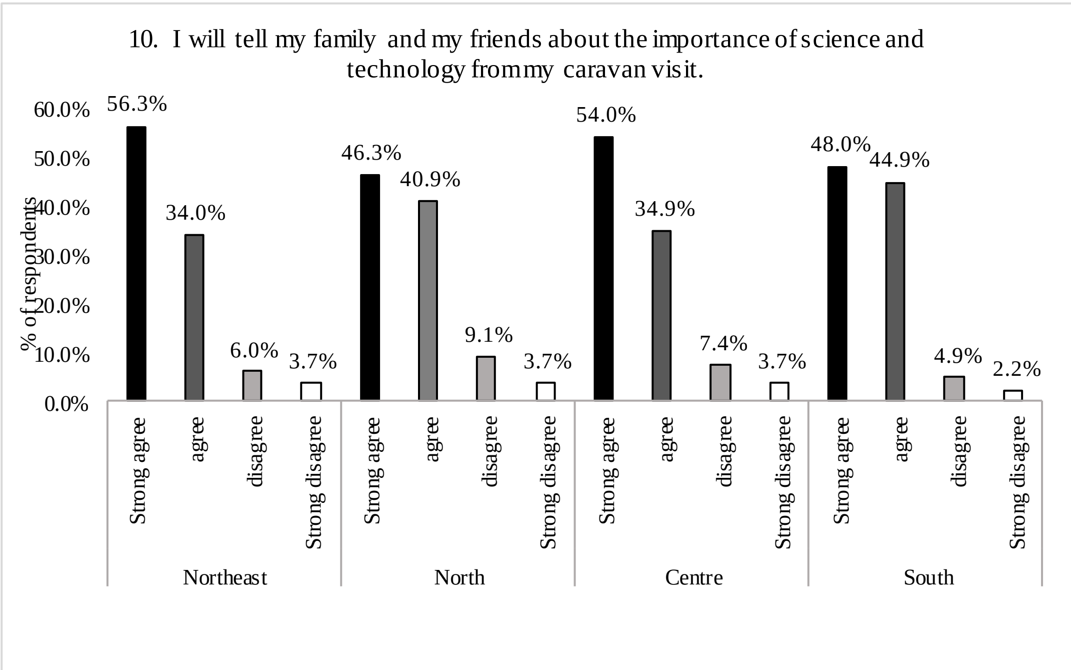


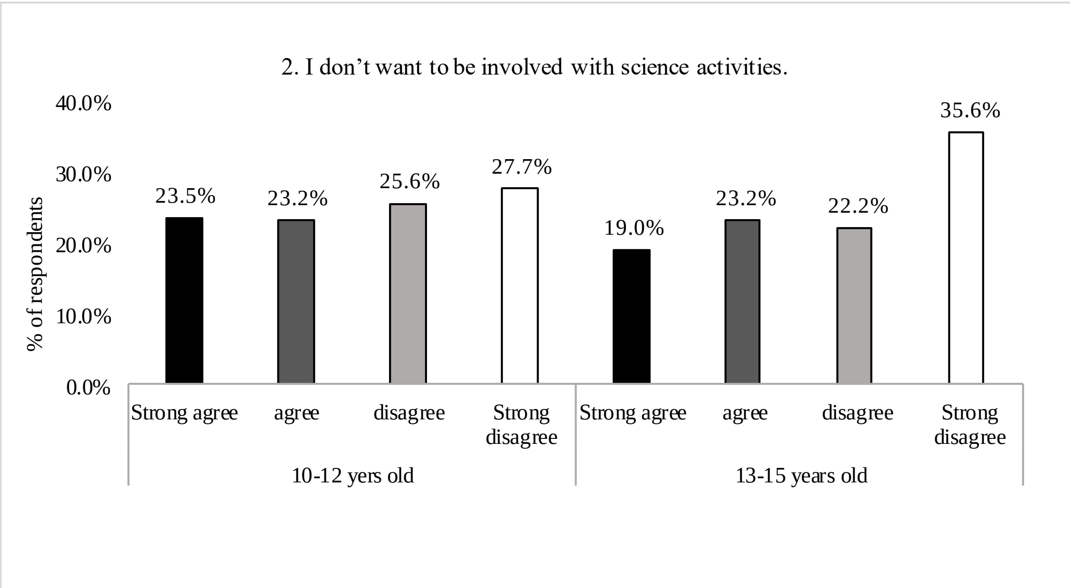
Figure 55: Learning outcome 10 Regional Differences



(3) Age

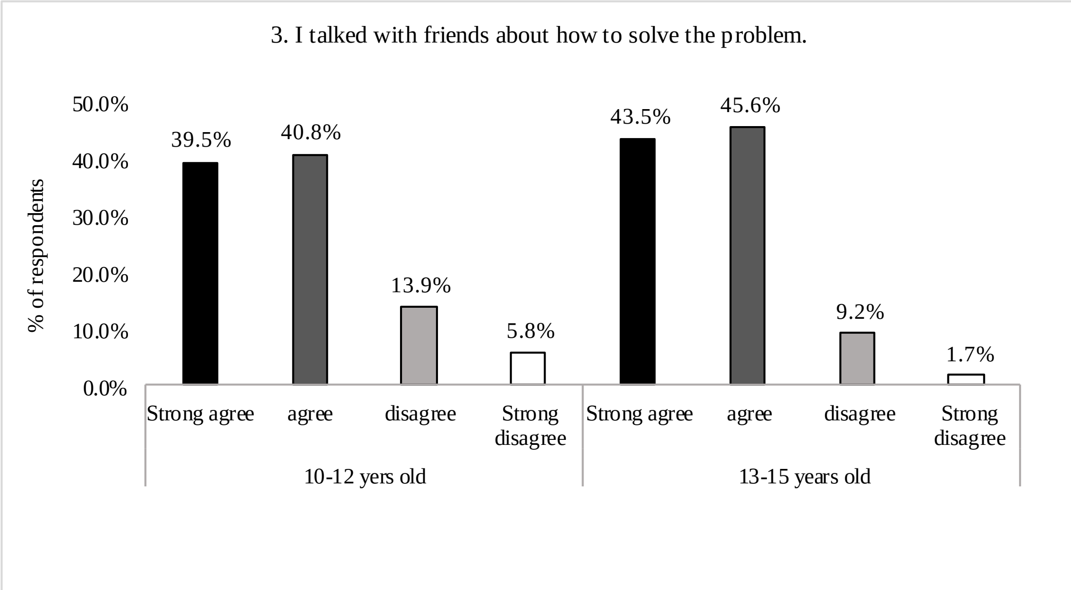
The Mann Whitney U Test was used to investigate the different of the data distribution in the learning outcomes of participants between respondents aged 10–12 years old (N=478) and 13–15 years old (N=922). The analysis indicated the data distribution of learning outcomes 2, 3, 4, 7 and 9 of both age groups were significant different with the *p-value* lower than 0.05 when using the Mann Whitney U Test. Whilst, most participants from both age groups disagreed with learning outcome 2 'I don't want to be involved with science activities' (see Figure 56 and Appendix C.16 and C.17), the older age group showed a higher level of disagreement with this statement at 57.8% (N=276) compared to 53.3% (N=491) of 10–12 year old participants (see Figure 56 and Appendix C.16 and C.17), suggesting that participants between 13–15 years old preferred to be involved with the science activities than those aged 10-12 years.

Figure 56: Learning outcome 2 Age Differences



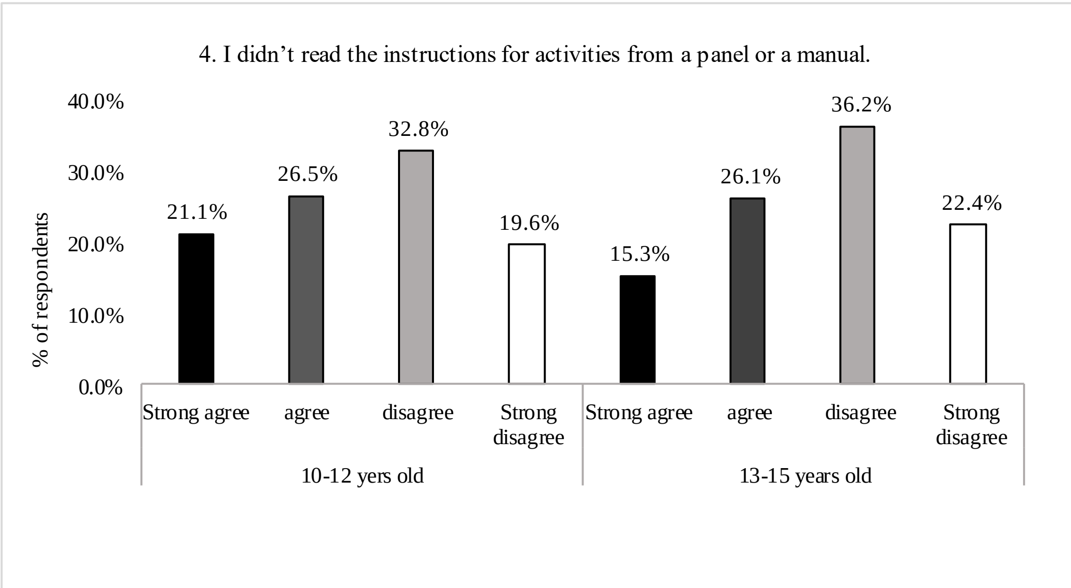
In relation to learning outcome 3, 'I talked with friends about how to solve the problem', most participants from both age groups agreed they did this. However, participants of the older age group had greater percentage in agreeing with this learning outcome compared to the younger age group, with percentage of 89.1% (N=426) for 13–15 years old and at 80.3% (N=740) for 10–12 years old (see Figure 57 and Appendix C.16 and C.17).

Figure 57: Learning outcome 3 Age Differences



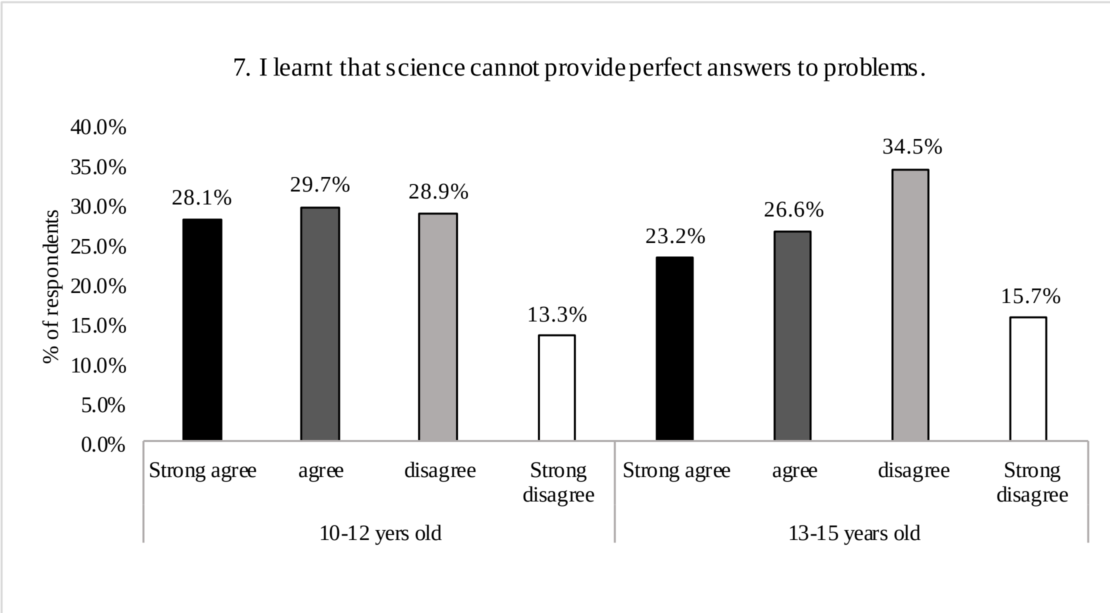
Additional greater number of participants aged 13–15 years old agreed that they had read the science activities instruction in learning outcome 4. 58.6% (N=280) of older participants disagreed with the statement ‘I didn’t read the instruction of activities from a panel or manual’, in contrast to the 52.4% (N=483) of 10–12 years old (see Figure 58 and Appendix C.16 and C.17).

Figure 58: Learning outcome 4 Age Differences



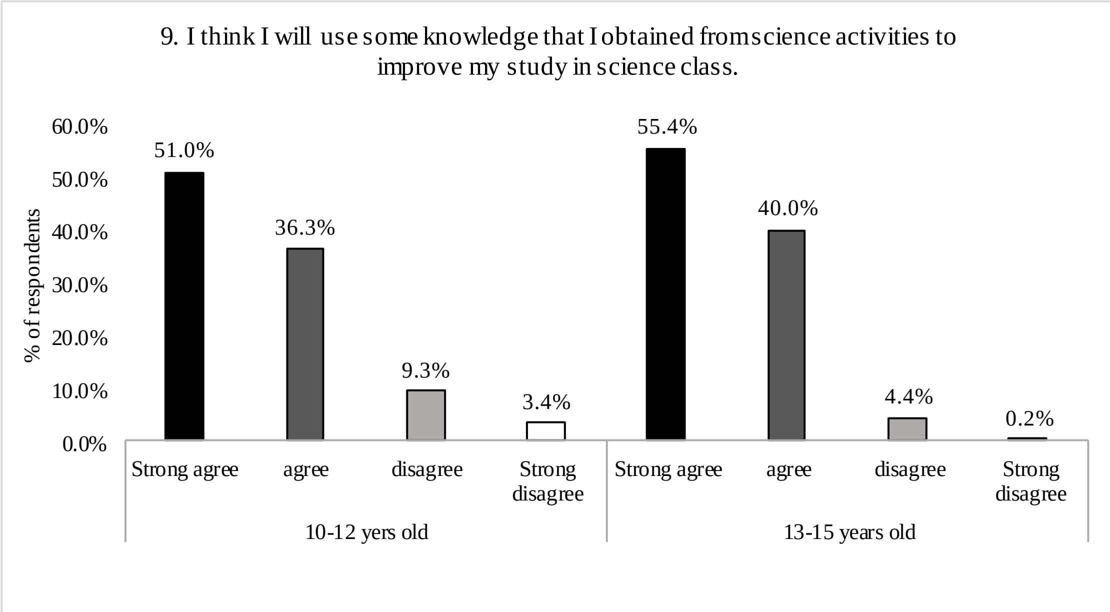
For learning outcome 7, ‘I learnt that science cannot provide perfect answers to problems’ a greater percentage 57.8% (N=533) of 10-12 years old participants agreed with this statement rather than disagreed (see Figure 59 and Appendix C.16). In contrast 49.8% (N= 238) of participants aged 13-15 years agreed (see Figure 59 and Appendix C.17).

Figure 59: Learning outcome 7 Age Differences



Finally, participants’ age 13-15 years old were more inclined to agreeing with learning outcome 9, ‘I think I will use some knowledge that I obtained from science activities to improve my study in science class’ than participants aged 10-12 years old. 95.4% (N=456) of 13–15 years old and 87.3% (N=805) of 10–12 years old (see Figure 60 and Appendix C.16 and C.17) agreed with this statement. Older participants were more easily able to see that knowledge obtained from interacting with the science activities could be used to improve science learning in classroom.

Figure 60: Learning outcome 9 Age Differences



(4) Gender

In investigating the learning outcomes of participants by gender, the data distribution of responses in the learning outcomes of male and female participants were tested by using a Mann Whitney U Test. The results of this testing indicated that there were significant differences in the data distribution of learning outcomes between male and female participants, with the *p-value* lower than 0.05 in learning outcomes 2, 4, 7, 8, 9 and 10.

In relation to learning outcomes 2, 4 and 7, more female participants disagreed with these three outcomes, when compared to male participants. Starting with learning outcome 2, 38.3 % (N=269) of female participants agreed that they didn't want to be involved with science activities, compared to 52.2% (N=364) of male participants. Only 38.6% (N=271) of female participants agreed that they didn't read the science activities instructions compared to 52.5% (N=366) of male participants. In relation to learning outcome 7, female participants (47.9%, N=337) were less likely to agree than male participants (62.3%, N=434) that they had learnt that science cannot provide perfect answers for problem (see Figure 61 to Figure 63 and Appendix C.18 and C.19).

Figure 61: Learning outcome 2 Gender Differences

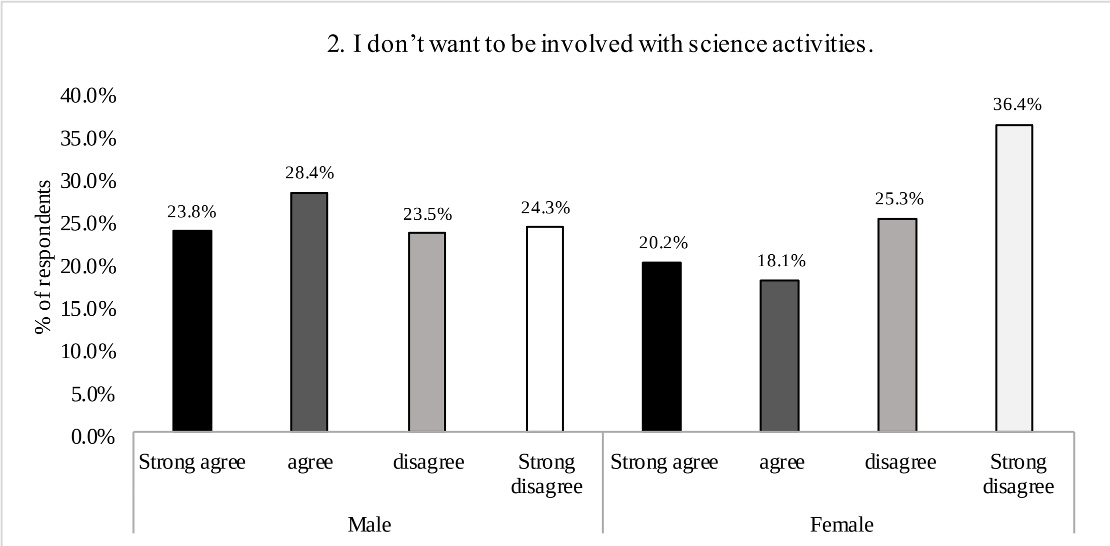


Figure 62: Learning outcome 4 Gender Differences

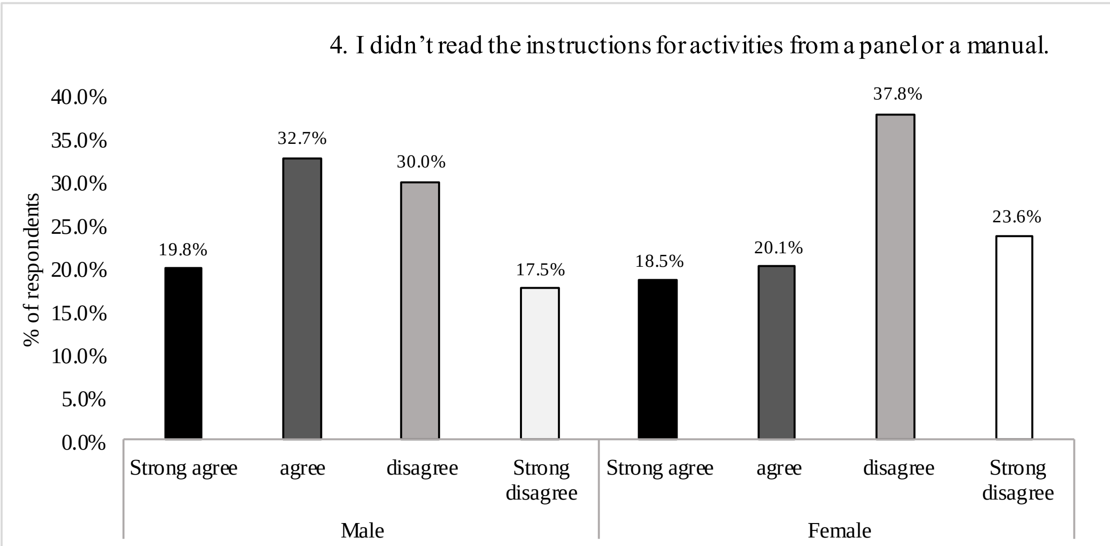
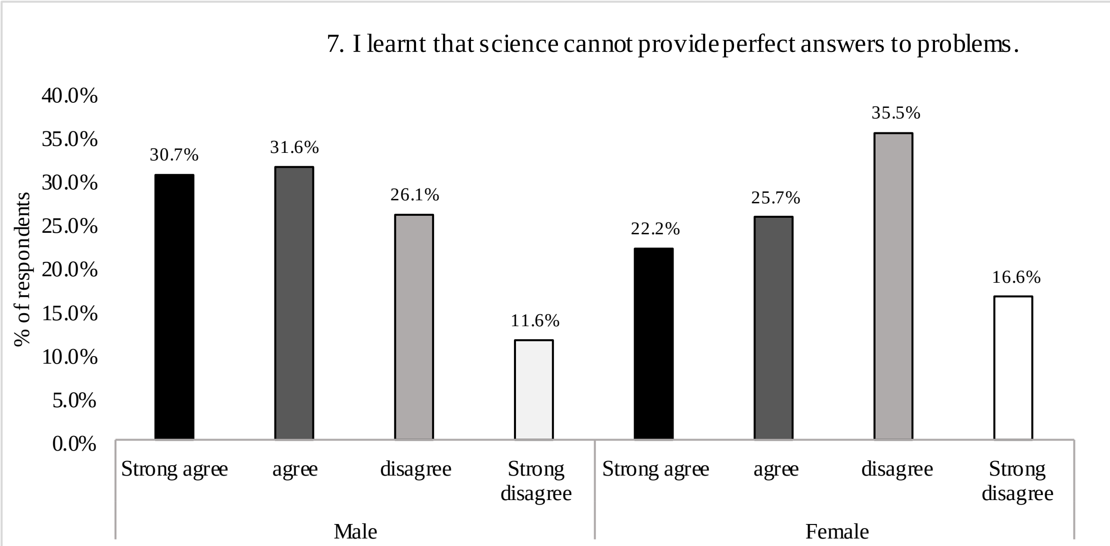
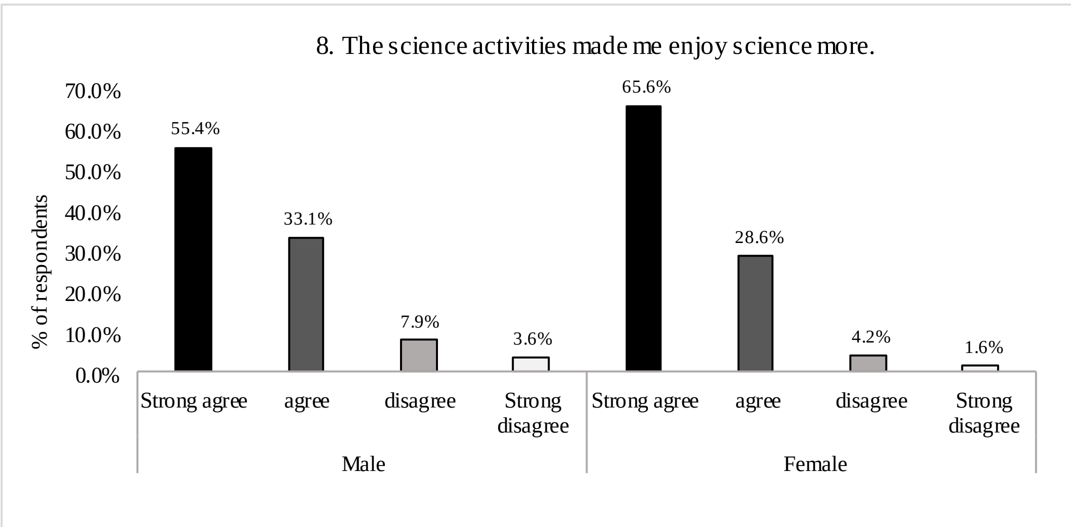


Figure 63: Learning outcome 7 Gender Differences



Greater number of participants from both groups agreed with learning outcomes 8, 9 and 10. However, Figure 64 showed more female participants (94.2%, N=662) agreed with the learning outcome 8, the science activities made me enjoy science more when compared to male participants (88.5%, N=617) (see Appendix C.18 and C.19).

Figure 64: Learning outcome 8 Gender Differences



Additionally larger numbers of female compared to male participants considered using knowledge they obtained from the science caravan engagement to improve their science learning in school (learning outcome 9), 91.3% (N=642) females agreed compared to 88.8% (N=619) of male participants and that they will tell their family and friends about the importance of science and technology (learning outcome 10) (see Figure 65 and 66). 93% (N=654) of female participants agreed that they would tell their friends and family about the importance of science and technology compared to 86.5% (N=603) of male participants.

Figure 65: Learning outcome 9 Gender Differences

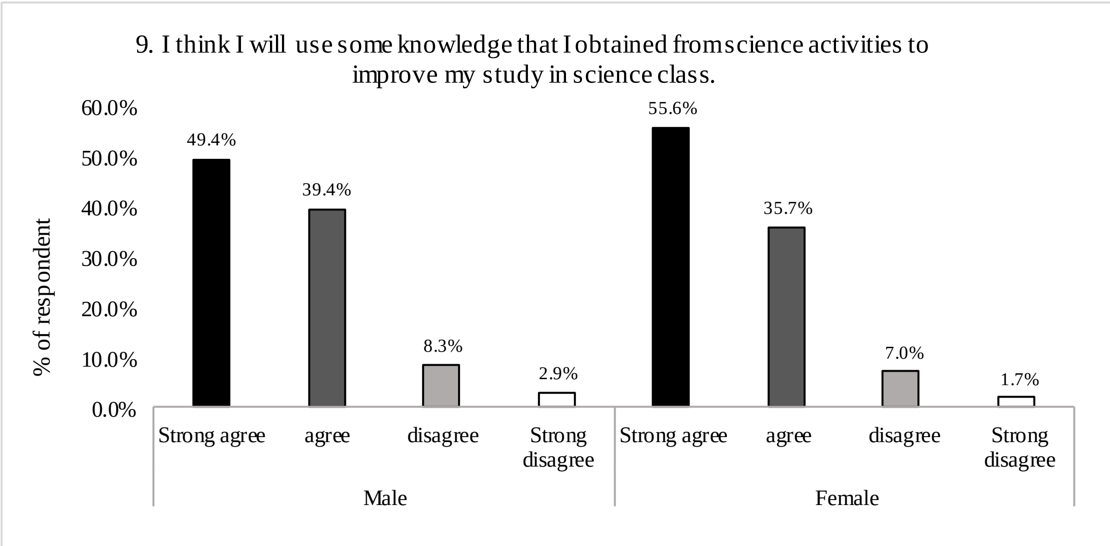
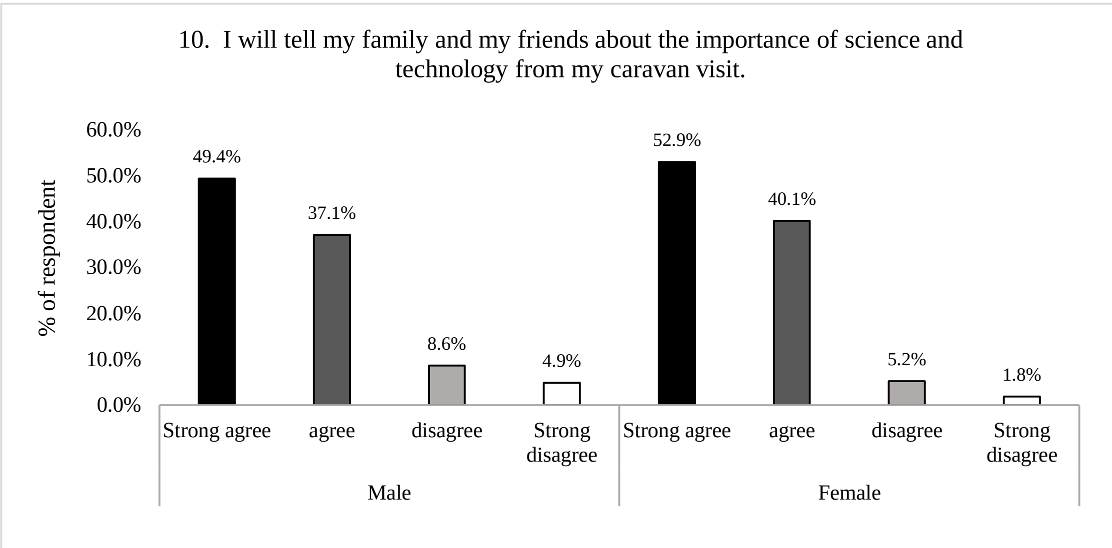


Figure 66: Learning outcome 10 Gender Differences



8.2.2 Qualitative results: Learning outcomes obtained from the Science Caravan engagement

This section presents the outcomes interviewees expressed after participating in the Science Caravan. These outcomes were found by examining students' responses to the questions: 'What have you enjoyed about the science caravan today?' (N=14); 'Did you learn anything new? What was it?' (N=38); 'What would you like to find out more about?' (N=29); and 'Is there anything else you would like to add?' (N=2). Teacher responses regarding the outcomes of the Science Caravan engagement were explored through the questions: 'In your view, what's most useful about the Science Caravan for your students?' (N=38), and 'In your view, what's most useful about the Science Caravan for you as a teacher?' (N=29). The results from the NSM staff regarding the outcomes of involvement with the Science Caravan were examined in questions: 'which are the most popular activities and why?' (N=21) and 'What are the strengths of the caravan?' (N=13).

Two themes were identified in these responses: the outcomes of teachers' engagement with the Science Caravan and the outcomes of young participants' involvement in the Science Caravan.

(1) Teachers

Table 22 shows that 29 responses from teachers and 6 responses from NSM staff identified outcomes for teachers who participated in the Science Caravan. There were 3 main outcomes for teachers: (1) teachers were inspired to develop science teaching in their classroom; (2) teachers obtained new scientific knowledge and understanding; and (3) teachers gained new ideas about teaching techniques.

Table 22: Outcomes of the Science Caravan engagement of teachers

Outcomes of the Science Caravan engagement	Count (N=response)				
	Teacher				The NSM staff
	Northeast	North	Centre	South	
(1) Teachers inspired to develop science teaching in their classroom	1	5	8	3	6
(2) Teachers obtained new scientific knowledge and understanding	-	-	1	-	-
(3) Teachers gained new ideas about teaching techniques	2	3	4	2	-

Note: from Appendix D.5 (3.4) and D.6 (2.3)

- **Inspiration**

Teachers and NSM staff indicated that teachers engagement with science activities in the Science Caravan inspired them to develop science teaching in their classroom for students (N=17 teachers, N=6 NSM staff). Particularly, science teachers with no science background found many ideas for teaching science via simple experiments and activities that would be useful to promote students' science learning. Tipprapa (a female non-science teacher from the guest school of the Northeast) described the science activities and experiments in the Science Caravan as interesting activities designed with simple and easy-to-access materials. Hence, she will use these activities to develop her science teaching for her students. Chompunuch (a female non-science teacher from the guest school of the South) stated that the science activities in the caravan also inspired her to develop science experiments from simple materials. She found that using even simple materials for experiments without science equipment allowed students to obtain scientific knowledge.

- **Knowledge and understanding**

Engagement with the Science Caravan also promoted better understanding and new scientific knowledge among teachers (N=1 of teachers). The Science Caravan was, in short, useful for supporting the teachers' science teaching. Saksuriya (a male non-science teacher from the guest school of the Centre) mentioned that he had gained new scientific knowledge from participating in the Science Caravan. Additionally, he also obtained better understanding of science principles from interacting with the hands-on exhibition, which was linked with the school science curriculum. He thought that this knowledge would be useful for promoting his own teaching and explanations of science principles for his students.

- **New ideas about teaching techniques**

The Science Caravan also offered many useful ideas and techniques for explaining science principles to participants (N=11 of teachers). These techniques were seen to be helpful for supporting the development of science experiments and activities for teaching students in a classroom. Rawiwan (a female science teacher from the guest school of the North) stated that she had observed in the Science Caravan many useful new techniques and ideas for explaining scientific knowledge to young people. From her view, these ideas will support her development of science experiments using simple materials for students. Moreover, she felt that the communication techniques of the explainers will be useful for encouraging students' focus on science learning in a classroom and for effectively explaining scientific knowledge to her students in a simple and clear manner.

Hence, participating in the Science Caravan has promoted development of teachers' science teaching. Ideas and techniques for doing simple experiments also inspired teachers in terms of how to teach science in their classroom. Moreover, teachers with no science background obtained new scientific knowledge and gained better understanding of the science and technology linked with the school science curriculum.

In summary, from the teacher interviews, teachers who are non-science teachers and have no scientific background, but have to teach a science subject often agreed that they gained new scientific knowledge, and they were inspired to develop their science teaching from the Science Caravan involvement. Otherwise, science teachers who had a scientific background and confidence in that area mentioned that they still gained new science teaching techniques that promoted their teaching in a science classroom.

(2) Students

The outcomes of students' engagement with the Science Caravan were reflected in 83 student responses, 38 teacher responses and 28 NSM staff responses. These outcomes for the young participants involved with the Science Caravan divided into 6 main outcomes: (1) enjoyment; (2) inspiration; (3) knowledge and understanding; (4) skills; (5) attitudes and values; and (6) behaviours and progression (see Table 23).

Table 23: Outcomes of the Science Caravan engagement of students

Outcomes of the Science Caravan engagement		Count (N=responses)								
		Students				Teachers				NSM staff
		NE	N	C	S	NE	N	C	S	
(1) Enjoyment	• Had fun watching the Science Show.	3	2	1	2	-	-	-	-	7
	• Had fun doing experiments/activities.	1	4	2	2	4	3	1	-	6
(2) Inspiring	• Inspired students to study more science and technology.	-	-	-	-	-	-	-	-	1
	• Inspired students to be scientists/ science communicators.	-	-	-	-	-	-	-	-	2
(3) Knowledge and understanding	• Obtained new scientific knowledge.	2	7	4	4	6	4	4	6	2
	• Gained better understanding of how science phenomena link with a science curriculum in a classroom.	1	-	1	2	-	-	-	-	1
(4) Skills	• Practised doing experiments/activities skills	3	2	3	-	2	2	2	2	3
	• Practised experiment equipment skills	3	-	1	-	-	-	-	-	2
	• Practised communication skills in communicating with other	1	-	-	-	-	-	-	-	-
	• Improved and developed social skills	1	-	-	-	-	-	-	1	-
(5) Attitudes and values	• Good attitude toward science as a subject	-	-	-	-	-	-	-	1	1
	• Awareness about the importance of scientific knowledge related to daily life	-	-	-	-	-	-	-	-	1

	• Better self-esteem among participants after they had to find the answers by themselves	1	-	-	-	-	-	-	-	1
	• Good attitude toward the NSM staff and the Science Caravan.	2	1	-	1	-	-	-	-	1
(6) Learning progression	• Studied more about interesting topics such as insects, fossils and dinosaurs	7	4	4	4	-	-	-	-	-
	• Shared new knowledge with family	1	-	3	3	-	-	-	-	-

Note: from Appendix D.4 (3.3), D.5 (3.4) and D.6 (2.3), NE: the Northeast, N: the North, C: the Centre, S: the Sout

- **Knowledge and understanding**

The interview data show that most interviewees (N=44) felt that students had gained new scientific knowledge and better understanding of science principles through participating in the Science Caravan. From the student interview, the results showed that most responses around gains were found from the North (N=7) and the South (N=6) student interviews. It was evident that students felt they had learned new science knowledge. Pinmuk (a female high school student from the host school of the South) mentioned the squeezing bottle experiment in the Science Show.

> In the squeezing bottle experiment, I learned about air pressure. I saw the presenter put the ethanol in the big bottle, and then she held up the flame to burn the ethanol. After it burned, she used her hand to seal the bottle, and the bottle crumpled. The presenter explained why the bottle crumpled. The bottle had no air after the fire burned it up, so when the presenter sealed the bottle with her hand, the air outside the bottle crushed the bottle.

Figure 67: Observing fossils and making the Chicken Voice

Navin (a male high school student from the Centre) said that he learned the science of sound from the chicken voice activity. This activity supported his understanding of the scientific principles of sound that he had learned in his classroom (see Figure 67). Adisak (a male high school student from the host school of the South) mentioned discovering new fossils he had never seen before in the life science exhibition room. The experience promoted their learning about fossils and encouraged them to learn more about different fossils and dinosaurs.

Among the teachers, Amponpan (a female science teacher from the host school of the South) stated that participating in the Science Caravan gave students new science knowledge and an awareness of the importance of science. The demonstrators presented both the knowledge and the significance of science and technology through the activities. The demonstrators also explained the scientific principles linked with everyday life to encourage participants to gain more knowledge and understanding and to thereby further raise participants' awareness of the significance of science. The interviews with teachers suggested that the Southern participants took the caravan involvement more seriously in regards to learning and focused on obtaining scientific knowledge, with a high intention that their students learn from the caravan engagement.

However, Bunyapat (a female science teacher from the host school of the Northeast) discussed the balloon experiments in the Science Demonstration room. The experiment helped her student gain better understanding of characteristics of air from blowing a balloon. In the experiments, her students learned about the characteristics of air. Air, as a substance, has a weight. Blowing into the balloon is pushing the air into the balloon, so it makes the full balloon heavier than the empty balloon. She also said that many experiments in the Science Caravan supported her students' science learning in the classroom.

- **Enjoyment**

The interview results yielded 38 responses indicating that participants had fun while doing the science activities, gaining support from the explainers and playing with friends in the Science Caravan, with participants in the North particularly mentioning that enjoyment had encouraged participants to engage with activities in the Science Caravan. Amitta (a female primary school student from the guest school of the North) said that making the chicken voice from the chicken cup made her laugh because the chicken cup clucked like a real chicken, so the chicken cup's sound was funny. Preaw (a female primary school student from the guest school of the North) said that she enjoyed the balloon experiment in the Science Demonstration room (see Figure 68):

> I liked the balloon experiment because it was a very funny activity. I blew up a balloon in the bottle, but my friend could not. While I blew the balloon I competed with my friend. I saw my friend’s face, which was very funny, and I laughed. My friend also laughed at my face too, and everyone laughed at us. After we finished, the explainer explained why I was able to blow up the balloon but my friend couldn’t. It was because my bottle had a small hole, whereas my friend had a balloon in a bottle without a hole, which meant he couldn’t blow up the balloon.

Figure 68: Blowing up the balloon in the bottle

However, other participants from other regions also enjoyed the Science Caravan engagement. Chompu (a female primary school student from the host school of the Centre) stated that the explosive paint tin in the show excited and surprised her because of the noise of the explosion. This experiment made her curious about the tin bomb; she wanted to know why it had exploded when heated. Therefore, she stayed focused on the show until the end. She said that she learned heat causes air to expand, and the expanding air caused the closed container to explode.

Figure 69: The explosion of the tin show

Regarding the NSM staff members' perspective, Rawipa (a female science communicator of the NSM) stated that the audience felt good and had fun with the show. She saw many audience members laughing and smiling while she was on stage. She was sure the show helped participants to have fun and enjoy learning science in a fun atmosphere. Additionally, Supranee (a science communicator of the NSM) observed that a fun atmosphere supports participants' interest in learning science with science activities and encourages participants to have more confidence in asking demonstrators' questions, communicating with others and trying to do activities on their own. About her Science Show experience, Supranee said that many audience members became confident after participating in the show; they came to talk to her and ask questions about the science in the show. She believes that the fun atmosphere helped her break the ice between her and the audience and encouraged participant confidence and responses to the show (see Figure 69). Enjoyment and involvement with the Science Caravan stimulated local young people to have more interested in informal science learning activities and to engage with scientific knowledge.

- **Skills**

Concerning skills, 28 responses (14 student responses, 9 teacher responses and 5 NSM staff responses) indicated that participants' experience in the Science Caravan developed their science skills, including experiment/activity skills (N=19); experiment equipment skills (N=6); communication skills (N=1); and social skills (N=2). The NSM staff results on activities development considered the promotion of science learning among participants in terms of learning skills development. The NSM staff's expectation for local participants in the Science Caravan was promotion of science learning skills. Such skills include intellectual skills, reading skills, and social and communication skills.

> In my caravan experiences, I found that science activities stimulated participants into trying new things to find the answer to the exhibits, activities and experiments. For example, in the materials science exhibition, some participants had no chance to do the electric circuit. The electric circuit exhibit encourages participants to find the right circuit to light up the display. During their examination to try and find the right circuit, the participant has to learn the relation between electricity and the light by playing with the exhibit, which involves sharing knowledge with friends about how to turn on the light with the right circuit. That supports social and communication skills.
>
> (Kreangkrai, male, science communicator, NSM staff)

In addition, the results from the student interviews, especially in the Northeast, showed that participants had the opportunity to develop their science learning skills based on experiments and sharing information. Nim (a female primary school student from the host school of the Northeast) mentioned her experience of participating in the Material Exhibition room. In the bicycle exhibit, she learned about the right material for the bicycle wheel by testing different types of material such as wood, aluminium and wool. She found that three types of material were not right for the bicycle wheel (see Figure 70).

Figure 70: Young remote students exploring different materials for a bicycle wheel in the material science exhibition

Moreover, Keng (a high school student from the guest school of the Centre) mentioned communicating with others during the activities. He said that he asked friends how to play with the exhibits in the life room and in the material room. In return, sometimes he explained to his friends how to do activities such as playing the tangram. He also stated that participating in the caravan helped him make new friends from other schools. The involvement with the caravan helped him developed his social and communication skills.

Additionally, Burin (a male science teacher from the guest school of the South) mentioned that most of the Science Caravan activities were science experiments that encouraged his students to try to do the experiments to find the answers. These experiments support development of scientific method skills including asking, hypothesising, reviewing information, experimenting and drawing conclusions. He also emphasised that participating in the caravan helped his students develop learning skills that could be applied to other subjects.

Hence, the involvement with the Science Caravan amongst local young participants promoted the development of doing science activities and using science experiment equipment, including developing social and communication skills, especially for the Northeast participants who have the lowest science performances.

- **Learning progression**

From the student interviews, 26 responses from four regions mentioned learning progression. In terms of progression, students mentioned extra studying of interesting science topics and sharing science experience with family members. Ford (a male primary school student from the host school of the Northeast) and Bambam (a female primary school student from the host school of the North) had similar responses. They discussed learning about fossils in the Life Exhibition room. They were impressed with the fossil of the oldest flower and the models of dinosaurs. They want to study more about plants and fossils, especially the fossil they saw of the oldest plant. Ford said that he wants to know more about the oldest plant fossil because he never knew that plant fossils could be older than dinosaur fossils, whereas Bambam wants to study more about different dinosaur species because she had never seen a fossil before. Som (a female primary school student from the host school of the Centre) referred to the balloon experiment in the Science Demonstration room. She said that blowing up a balloon in a plastic bottle is a simple and interesting experiment. She wants to try this experiment with her sisters and parents. She thinks her family members will like this activity.

- **Attitudes and values**

In terms of attitudes and values, 10 responses (5 student responses, 1 teacher response and 4 NSM staff responses) suggest that participants displayed a good attitude towards science as a subject (N=2); became aware of the significance of scientific knowledge related to their daily life (N=1); developed their self-esteem by realising that they could learn by themselves (N=2); and displayed a good attitude toward the NSM staff and the Science Caravan (N=5) (see Appendix D.4, 5 and 6). The interview results indicated that, by participating in the Science Caravan, some participants gained a more positive attitude towards science and more awareness of the significance of science and technology. In addition, participants mentioned that participating in the caravan gave them more confidence to share their ideas and try new experiments and built up their self-esteem. Somsak (a male primary school student from the South) stated that science was a difficult subject for him, and he thought that science was far from his life. In his opinion, science was not a fun subject and only for clever students. Somsak also noted that in his science class, he learned science from his books and from the teacher rather than by doing experiments. He said that it was difficult to understand science phenomena from pictures and information in books. During his Science Caravan experience, he found that many science experiments in the caravan helped him to clearly understand the science curriculum content of his class. He said that he started to like science after participating in the caravan.

From the teachers' view, Panya (a male science teacher from the host school of the Centre) stated that the informal learning atmosphere and the demonstrator support in the Science Caravan encouraged participants to be more interested in science. In an informal atmosphere, students have more confidence to interact with activities, and many exhibits were designed to help students learn by themselves. The humour of the demonstrators also prompted students to have a more positive attitude towards involvement with science activities. Students came to enjoy the subject of science and became aware of its importance.

- **Inspiration**

Three responses only found from the NSM staff, they stated that the Science Caravan inspired participants to study more science and technology by helping the participants to realise the significance of science and how it relates to their everyday life. The participation also inspired these participants to be scientists and science communicators because participants were impressed with the NSM staff's roles and work in the caravan.

Therefore, the significant outcomes of the young participants' engagement with the Science Caravan included enjoyment, inspiration, knowledge and understanding, skill development, attitudes and values, and behaviours and progression.

8.3 Limitations and Future needs for the Science Caravan

This section explores limitations of participating in the Science Caravan, and the needs of local participants for potential future development of Science Caravan.

8.3.1 Limitations of learning with the science activities in the Science Caravan

In exploring the limitations of learning within the Science Caravan activities, 11 limitations (see Table 24) were found from 52 responses of students, teachers and NSM staff. The responses comprised 14 teacher responses to the question: 'Are there things about the Science Caravan you would change?'; 22 student responses to the question: 'What didn't you like (in the Science Caravan)?'; and 16 NSM staff responses to the question: ‘What are the weaknesses of the Science Caravan?’ These limitations hinder science learning from the Science Caravan.

From Table 24, the results show there are eight limitations mentioned by students, three limitations from teachers, including five limitations from the NSM staff. Three limitations were only identified by the NSM staff; the limited the learning performance of young participants, language barriers (with minority groups) and limited communication skills of explainer, suggesting the explainer’s limitations can also have an effect on informal learning experiences of local participants.

In this research, exploring the limitations of learning in the Science Caravan, most responses identified activities that did not support different groups of participants. This issue was noted in 17 responses (N=7 of students, N=8 of teachers and N=2 responses of the NSM staff) (see Table 24). In the NSM staff interviews, 2 respondents identified the limitations in activity designs and development. Activities/ experiments were not designed for broader groups. Representing the opinions from students, for example, Fang (a female high school student from the guest school of the South) mentioned that the Chicken Voice was too easy for her; she needs the caravan to provide more difficult and challenging activities to promote her science performance.

> I thought the Chicken Voice was too easy for high school students. This activity should be provided for primary school students. I want to learn more varied science topics and more difficult ones. The content of activities should link with the school science curriculum.

Table 24: Limitations of learning with the science activities in the Science Caravan

Limitations of learning in the Science Caravan	Count (N=responses)								
	Student				Teacher				NSM staff
	NE	N	C	S	NE	N	C	S	
(1) Activities did not support different groups of participants	3	2	1	1	1	4	2	1	2
(2) Too many students in each class	1	4	1	-	-	-	1	3	2
(3) Time for activities was too limited	1	-	-	-	2	-	-	-	-
(4) Limited the learning performance of young participants	-	-	-	-	-	-	-	-	5
(5) Unclear labels for hands-on exhibition	1	-	1	-	-	-	-	-	-
(6) Insufficient interaction with some exhibits	1	-	-	-	-	-	-	-	-
(7) Limits to working with others	-	1	-	-	-	-	-	-	-
(8) Experiment was too noisy	2	-	1	-	-	-	-	-	-
(9) Fear of interacting with some exhibits	-	-	1	-	-	-	-	-	-
(10) Language barriers (with minority groups)	-	-	-	-	-	-	-	-	6
(11) Limited communication skills of explainer	-	-	-	-	-	-	-	-	1

Note: from Appendix D.4 (3.2), D.5 (3.5) and D.6 (2.2), NE: the Northeast, N: the North, C: the Centre, S: the South

Additionally, eight responses from teachers referred to some of the Science Caravan activities as too difficult for primary school students or too easy for high school students. The opinion of Tipprapa (a female non-science teacher from the guest school of the Northeast) reflects this issue:

> While observing my students engaged with the Science Caravan, I thought the science of the Material Exhibitions was too difficult for my primary school students. Most of the exhibits' content linked with a high school curriculum. For example, her students took too much time doing the electric circuit, and they felt this activity was too difficult. Some of the students did not want to continue doing this activity to find out how to make the display light up.

Next, having too many participants was identified as a limitation by students, teachers and the NSM staff (N=12). The science activity designs intended to engage only a limited number of participants at once; estimates were for $\leq$50 for each of the Science Demonstrations, Science Games and science exhibitions, but for $\leq$500 for the Science Show (see Chapter 4 section 4.3). However, all of the Science Caravan trips had a higher number of participants engaged with each activity at any one time. This limit hindered participants' ability to obtain scientific knowledge while learning in the Science Caravan. Some participants did not have an opportunity to interact with certain exhibits, experiments and Science Games because there were too many participants. Chunsuda (a female high school student from the host school of the North) described this problem in her experiences with the Science Caravan.

> I thought there were too many participants in the exhibition classes, the ones for life science and the science of materials. I had no chance to take part in these exhibits or to do the experiments. I wanted to test the materials for the bicycle wheel, but I didn't get a chance to play with this exhibit. If the number of participants was limited, I might have gotten an opportunity to play with the bicycle.

Language barriers were the third limitation, as indicated by six responses of the NSM staff. Language limitations had a negative effect on learning, especially for minority groups that spoke different languages. Additionally, using scientific jargon in communication with participants as young as primary school students made the content too difficult. Kraisak (a male science communicator of the NSM) indicated that using scientific jargon had hindered the learning of participants, especially primary school students. He said that sometimes he could not avoid using science jargon during the Science Show because he needed participants to remember certain terms. But as a result, sometimes participants did not understand these words and stopped focusing on the show. He tried to explain the meaning of jargon words linking new terms with daily life activities, including presenting the terms within a humorous environment in order to promote better understanding among participants and focus on the show. Ekkaparp (a male science communicator of the NSM) referred to his own Science Caravan experiences in the North of Thailand.

> From my experiences of the Science Caravan, in demonstrating experiments or explaining exhibitions to minority groups, the translators for these groups were important supporters for doing activities with them. Doing activities for these groups took too long. Most minority audiences did not understand all of the content when interacting with science activities in the Science Caravan because of the limited number of translators and barriers of translation.

The fourth limitation reported was the limited reading and writing abilities of participants; this limitation was found from the NSM staff responses (N=5) and could hinder Science Caravan activities that were designed to promote self-learning among participants. Chitthima (a female science communicator of the NSM) indicated that limited reading and writing skills, including lack of scientific knowledge, amongst participants had obstructed their science learning during their interaction with science activities in the Science Caravan. NSM explainers had to help these participants learn science from these activities. The activities took too long for them, and explainers could not individually help each participant interact with exhibits because there were too many participants.

The further seven limitations of learning in the Science Caravan included, a lack of opportunities to engage with all of the activities in the Science Caravan, poor labelling, less interactive content, limited team working, noise, fear of exhibits, and poor communication skills on the part of NSM staff. (N=3 by N=2 of students and N=1 of teachers).

8.3.2 Needs of participants for future Science Caravan development

When exploring student and the teacher interview results, there were three categories of needs that arose which may be relevant for future development of the Science Caravan as well as similar regional activities: annual visits (N=21); activities (N=61) and project evaluations (N=1) (see Table 25). These results were found from student and teacher responses to the question ‘Is there anything else you would like to add?’ (N=83: N=33 of students and N=50 of teachers).

(1) Revisit/Annual visit

Six responses from teachers and 15 responses from students indicated the need to be involved with the Science Caravan again, and they hoped that the Science Caravan would visit every year. Man (a male high school student from a host school of the South) expected that the Science Caravan would visit his school again. He found that there were a lot of interesting science activities in the caravan, he also enjoyed participating in the Science Caravan. Kitiya (a female science teacher from a host school of the Northeast) also expected that the Science Caravan would visit her school every year because of the number of students from her and neighbour schools who could benefit from engaging with informal science learning. The caravan is useful for remote students who are located far from other informal science learning settings.

(2) Activity management and development

Teachers and students also indicated a need for science activity management and development. Seven participant needs were found from teacher and student interviews, including (1) limiting the number of participants (N=21); (2) developing new activities and more variety (N=11); (3) offering more activities for different groups of participants (N=10); (4) introducing more science topics (e.g. cosmology, life, chemistry) (N=3); (5) extending time for participating in each activity and visiting each location (N=10); (6) explaining any basic knowledge of science activities to participants before performing activities (N=1); and (7) more presents for young participants (N=5).

Table 25: The needs of participants for Science Caravan development

Theme	Coding	Count (N=response)							
		Student				Teacher			
		NE	N	C	S	NE	N	C	S
Annual visits	Revisit every year	5	4	3	3	2	2	-	2
Activities	Limit the number of participants.	-				5	5	5	6
	Develop new activities and more variety.	2	3	2	2	-	-	1	1
	Offer more activities for different groups of participants.	-	-	-	1	1	1	2	5
	Introduce more science topics linked with the school curriculum (e.g. cosmology, life, chemistry).	-	-	-	-	1	-	1	1
	Extend time for participating in each activity and visiting each location.	-	1	2	-	3	1	1	2
	Explain any basic knowledge that participants need to know before performing activities to help them have better understanding.	-	-	-	-	-	-	1	-
	More presents for young participants	-	3	1	1	-	-	-	-
Evaluation	Evaluate the Science Caravan after finishing each location to promote further improvement and development.	-	-	-	-	-	-	1	-

Note: from Appendix D.4 (3.4) and D.5 (3.5), NE: the Northeast, N: the North, C: the Centre, S: the South

- **Limit the number of participants**

According to the interview results, participants' involvement in the Science Caravan was limited because there were too many participants included in each class. Some participants did not have the opportunity to interact with all activities. Therefore, this limitation has an effect on some participants being able to obtain scientific knowledge. Results from the teacher interviews show 21 responses which identified that having too many participants may obstruct science learning for young participants. Instead, they need the caravan team to maintain a limited number of participants in each class to promote maximum engagement with the science activities. Damronsak (a male science teacher from a host school of the Centre) stated that too many participants being involved with each activity was a cause of some students being unable to interact with science activities. Thus, these students lacked opportunities to learn science through science activity engagement.

- **Develop new activities and more variety**

Two responses from teachers and nine responses from students indicated the development of new and more variety activities as a need for Science Caravan participants. Therefore, some students who had experience participating in NSM activities may have been involved with the same activities as the Science Caravan. Having been exposed to these activities already, they felt that they had nothing to gain from Science Caravan engagement. Sitisak (a male science teacher from a host school of the South) mentioned that some students had previously visited the NSM, particularly high school students, and they knew about some of the activities. Examples include the life science exhibitions, Science Games and Science Show. Learning from identical activities does not support students in science performance development. Hence, he suggested that the Science Caravan should develop and change its activities to new activities every year and consider increasing the different interesting science activities to promote obtaining new scientific knowledge and science performance development for young participants.

- **Offer more activities for different groups of participants**

Results from nine teacher responses and one student response indicated that the development of varieties of activities is a participant need because there are different groups of participants engaged with the Science Caravan. A variety in activities may promote science learning of different groups of participants such as different ages, genders and knowledge backgrounds. Fang (a female high school student from a host school of the South) suggested that the chicken voice activity should be offered for primary school students rather than high school students, because it was too easy for her. She mentioned that she would ask that the NSM staff to develop a variety of activities and different levels of difficulty, as she would like to practice more challenging science activities. Additionally, Amponpan (a female science teacher from a host school of the South) said that if the caravan provided more and different activities and content, it would further promote young participant development of scientific learning and performance.

- **Introduce more science topics linked with the school curriculum**

Introducing more diverse content and topics linked with the school curriculum such as cosmology, science of life, and chemistry were found from 3 teacher responses. The respondents believed that the development of science activities linked with the school curriculum would better support science learning and teaching in schools. Damrongsak (a male science teacher from a host school of the Centre) explained his teaching of cosmology and chemistry in his science class. He uses photos to teach cosmology and science experiments from YouTube to teach chemistry. Using these methods, he found that many students feel that these subjects are too difficult for them, and they fail in the science exams. Damrongsak believed that if students had more opportunities to interact with hands-on exhibits of cosmology and were involved with chemistry experiments, this would promote a better understanding of these topics. Using the experience of the Science Caravan as a channel, he believed that the NSM team should develop hands-on exhibits and experiment activities which support teaching and learning science in school. He hoped that the future Science Caravan would have more different content and activities linked with the science curriculum to promote learning and teaching science in a classroom.

- **Time for participating in each activity and visiting each location**

Being allotted too short of a time period for participating in the Science Caravan was an obstacle to science learning through the science activities in the caravan. Therefore, one need expressed by participants was that the time for participating in the Science Caravan be extended. This need was mentioned in seven teacher responses and three student responses. Chompu (a female primary school student from a host school of the Centre) said that the time allowed for doing activities, especially the time for playing Tangram, was too short, and she needed more time to solve the problem. Moreover, Penpan (a female high school student from a host school of the North) said that the time allotted for executing each activity was too short. She needed more time to learn in the Science Caravan. She added that she wanted to spend more time studying all of the exhibits in the science of life room and the science of materials room. She thought that these exhibits were interesting and their content of was linked with her science curriculum. She suggested that if the caravan extended its time for performing activities, she would learn and obtain more scientific knowledge to promote her learning in school.

- **Providing basic knowledge to participants before beginning activities**

One response from a science teacher from the Centre (Tippawan) identified that explaining any basic knowledge that participants needed to know before beginning activities would promote participants having a better understanding of the science involved. This basic information should be the instructions of activities to support participant learning from science activities such as how to interact with exhibits to obtain knowledge, the rules of engagement with the activities, and what participants could expect gain from engagement. Moreover, this basic knowledge would allow participants from different knowledge backgrounds to become ready to perform the activities together.

- **More incentives for participants**

Furthermore, five participant responses identified offering presents for young participants as a need for them. These respondents suggested that involvement with all activities should be rewarded with presents for those who performed them well, gave the correct answers for a science quiz, or volunteered for the show as a helper for the demonstrator. Presents were offered in some of these circumstances, but the participants stated that these presents were not enough. These students expected that the Science Caravan would provide more presents, and stressed that these presents would increase participant self-esteem.

(3) Project evaluation

The possibility of routinely providing an evaluation of the Science Caravan was mentioned by Jitree, a female science teacher from a host school of the Centre. She suggested that an evaluation of the Science Caravan would be a useful method to promote the effective development of the Science Caravan. The NSM staff can learn from enquiring into the needs of participants and their reflections of the experiences of engagement with the Science Caravan. This type of study may help the NSM staff gain a better understanding of the needs of participants related to the limitation and promotion of science learning through Science Caravan engagement. Additionally, this knowledge would support the development the Science Caravan for all of the participants. Therefore, additional evaluation was also identified.

In comparing the differences between the student's and the teacher's needs for the Science Caravan development, there are four needs that teachers required; limit the number of participants, give introductions to science activities that linked with the school curriculum, provide more explanations of basic science knowledge and evaluate the Science Caravan project to promote its further development. Whilst, students stated that they would like more rewards from their Science Caravan engagement.

In conclusion, exploring, revisiting, improving activities and investigating the Science Caravan project were the needs of the participants who were all identified as needs amongst those involved in the Science Caravan.

Chapter summary

The results in this chapter have addressed question 4, which asks *'What learning and other outcomes do young people obtain from participating in regional informal science activities?'*

This study indicated high levels of agreement to a series of statements on science and technology amongst all participant groups (by region, age and gender) before engagement with the Science Caravan activities. Subsequently, some attitudes had changed with some participants especially, some of the North participants being more wary that science can make life change too fast and science and technology can damage people's moral senses but it is difficult to say if these are necessarily problematic perspectives, they may show a growing awareness of the relevance of science and technology to life, as well as the complexity of science and its role within society. However, in the main highly positive views were confirmed, with most participants still believing in the benefits and importance of science and technology, including in making life healthier, easier and comfortable, and its importance for the country's development. More than 80% of participants in each region had positive attitudes towards science and technology. There were not obvious trends in regards to the attitude statements at the regional level, the age groups, or by gender.

In examining the learning outcomes from engaging, most participants showed high levels of agreement that the learning outcomes had been met, wanted to be involved in the activities and were following instructions. At the regional level, there were no clear trends around the variations of learning outcomes, but from the questionnaire results, there are some different results of learning outcomes compared between regions. More than 50% of the Northeast and the North participants did not read the activities or the exhibition instruction, and related with the student interview results, they most enjoyed interacting with the activities or the exhibitions directly. Whilst, most Northern participants identified enjoyment was the learning outcome that they gained from the caravan engagement. For the Southern participants, most indicated that they gained new scientific knowledge, and they want to use this knowledge to promote science learning in a science classroom, and in the student interviews, the Southern participants also stated that they needed many science activities and would like more difficult activities, as well as more science experiments in the caravan.

In exploring the different age and gender groups, there were differences by age and gender. Older participants aged 13-15 were more likely to want to be involved in science activities, to talk with and problem solve with friends, to read instructions, and to anticipate using their learning within their science classes. In terms of gender female participants were more likely to agree that they wanted to be involved in science activities, to read the instructions, to enjoy the activities, and to say that afterwards they would talk about it with their friends and family or use the learning in school.

Despite these variations by age and gender, more than 80% of all of participants indicated attaining new science knowledge, promoting social skills development, increasing self-confidence in presenting ideas in front of others, enjoying science activities, using knowledge from the science caravan to support learning in school, and sharing information to encourage science awareness to others after engagement with the Science Caravan. Additionally, local teachers obtained new scientific knowledge and gained new ideas for teaching science. These in turn, also inspired local teachers to develop their science education practices.

The research results included eleven limitations mentioned by students, teachers and the NSM staff which are currently impairing participants learning within the Science Caravan project. These included how they support different learners, the numbers and time offered to learners, how activities are designed and supported and the pre-existing skills and experience of both participants and NSM staff. However there was also a desire for more regular visits and various suggestions as to how the regional activities might be improved, including via evaluation.

Next. Chapter Nine will discuss '*How can this learning be applied to other informal science communication projects at a regional level?'*

Chapter 9
Discussion

Overview

This thesis employed a regional analysis to investigate the factors affecting the engagement of young people in Thailand with informal science learning. This chapter comprise of two important sections. Firstly, the discussion focuses on each of the first four research questions as follow:

(1) *What settings or resources are available to young people for informal science learning at the regional level?* This section considers what informal science learning resources as physical context (Falk and Dierking, 2000) are available at the regional level, and then discusses how the most significant of these resources play an important role in promoting formal science learning amongst young Thai participants.

(2) What are the main factors affecting the experiences of Thai young people in informal science learning? This section examines the key factors affecting young people's learning experiences in informal science learning and situates this informal science learning according to the contextual learning model of Falk and Dierking (2000).

(3) *How do informal science learning activities meet the needs of different demographic groups?* This section considers how informal science learning activities meet the needs of different demographic. In this discussion, the relationship between informal science learning activities and participants' interaction with these activities based on VARK and VEF (Ainsworth and Eaton, 2010; Barriault and Pearson, 2010) in terms of whether knowledge is constructed is discussed, including exploration of the preferred activities identified in the Science Caravan

(4) What learning and other outcomes do young people obtain from participating in regional informal science activities? This section

considers the outcomes of engaging with regional informal science activities in the Science Caravan. This section employs the Generic Learning Outcomes (GLOs) criteria to examine the caravan's outcomes.

Secondly, in investigating research question five; *how can this learning be applied to other informal science communication projects at the regional level?* The chapter draws on the discussion of the four research questions together to answer this question. The chapter closes by creating a series of recommendations as to how the research findings might be applied to develop other projects focused on regional informal science communication in response to question five.

9.1 Discussion

There are four main sections consisting of the discussion of the first four research questions. This knowledge is used to investigate research question five.

9.1.1 Question 1; 'What settings or resources are available to young people for informal science learning at the regional level?'

In the UK and US, science museums and discovery centres, zoos, aquariums and nature centres are significant informal science learning spaces; these spaces promote young people's interaction with exhibits and activities, which inspires curiosity and future inquiry; this in turn leads to better understanding and scientific knowledge outside schools (Bell *et al.,* 2009; Wellcome Trust, 2012). These informal science learning spaces have been designed to support the science learning of visitors regarding real-world phenomena; by participating in science programmes, exhibits and activities offered in these spaces, visitors can pursue and develop science interests, participate in scientific inquiry and make sense of science (Falk, *et al.,* 2014). Settings or recourses are considered as physical contexts in the contextual informal learning model of Falk and Dierking (2000). This context can be locations, venues, institutes, museums and centres promote free choice learning of people.

In this research, most participants identified the public library as the most significant informal learning resource for promoting the science learning of young people at the local level in Thailand (see Chapter 5, sections 5.2 and 5.3). Public libraries are a traditional learning space; first established in 1916 to promote education amongst

Thai people (Nimsomboon, 2003). Public libraries are important informal learning spaces for local people, who can access these libraries without any payment, and frequently use them for educational purposes rather than for entertainment (Indrarakulchai, 2001). Public libraries often support formal environments, which assign work that necessitates searching for knowledge in a learning space and this has been recognised in other work on informal learning environments, including in the UK (Hooper-Greenhill, 2007).

The results of this study suggest that public libraries provide many kinds of resources including science books, computers and internet access, including free Wi-Fi for visitors (see Chapter 5, section 5.3). By doing so, they offer a significant service in Thailand to promote young people's science learning outside of school.

In some regions, national parks and zoos are also significant informal learning spaces to promote informal science learning for people (Falk, 2005). The national park, as a significant informal learning setting, was selected as the favourite learning site for many participants, especially amongst those from the northeast (see Chapter 5, section 5.2). The location of national parks was a key factor in this; it was near the Science Caravan stop in the Northeast and so easily reached by caravan visitors, an important practical factor. Environments such as the Phu Lang Ka National Park in Nakhonphanom province offer local students an opportunity to learn about natural science, such as the relationship between the environment, ecosystem, animals and forest, by observing and presenting further information after the visit within school. Visits to the national park may thus promote the development of young peoples' science performance (see Chapter 5, section 5.3). A similar project, the Urban Advantage Program (the UA programme), a cooperation between New York City Department of Education and eight Informal Science Education Institutes in the US, provided zoo and national park visits to promote increased achievement in science amongst young people in New York City. They found that attending the UA programme amongst school students similarly promoted increases in student performance in science (Weinstein *et al.*, 2014).

Zoos were the third most popular informal learning space that participants identified (see Chapter 5, section 5.2). Visits to a zoo were seen to promote natural science learning amongst young people, who are able to observe animals' lives and habitats first hand and to interact with the zoo's activities. Previous studies have indicated zoos are significant learning spaces that promote local engagement with natural science; including increases in knowledge obtained from visiting and observing animals, as well as being a source of enjoyment (Lai, 2012; Falk *et al.*, 2008; Falk, 2005).

Even though public libraries, national parks and zoos are significant places promoting informal science learning for local young people in Thailand as found in other research, this research also found the school library to be a significant location (see Chapter 5, section 5.3). For remote young people, school is a significant factor in encouraging young people's science learning by providing learning resources and science learning-teaching for students (Gerber *et al.*, 2001 and Stocklmayer *et al.*, 2010). For underserved Thai students in remote areas, school libraries played an important role in promoting the education of local people, especially young people who live in villages that are located far from the public library. Today, the school library provides science books and media, including free Wi-Fi, to support students. However, the school library has limits in some services such as the limits of computer and Wi-Fi services, and the up-to-date nature of books for local students.

Another significant way of accessing science news and information was using online search technology, especially via a home computer with internet access, via an internet café service or free Wi-Fi from a public library or local community organisation. Any of these points of access to the internet were viewed as helpful methods that supported participants' development of scientific knowledge, especially for their science homework. Online technology helps young people immediately access specific science information regardless of their physical location (Srisawat, 2012), and has been recognised in past research, as a primary site for people when they are first searching for science information (Bell *et al.*, 2009) However, in this study, participants tended to use online access to support their efforts to complete science homework rather than to search for interesting or spontaneous scientific knowledge in their own time (see Chapter 5 section 5.3).

In answer to the question "what settings and resources are available to young people for informal science learning at the regional level" this research found that the public library and school libraries were identified as the most significant informal learning settings supporting local people's science education, including the national park and Zoo. Whilst, the internet and Wi-Fi technology become increasingly important for promoting local young people's approach to scientific knowledge increasingly.

9.1.2 Question 2; 'What are the main factors affecting the experiences of Thai young people in informal science learning?'

The results presented in Chapter 6 suggest that seven factors—school, teachers, family, friends, government, other organisations (local community, university and private companies) and participants themselves (expectation, prior knowledge and skills)—affect young people's science learning.

These factors can both support and inhibit science learning. The results suggested that teachers, friends and family, as well as some learning materials such as books and computers as previously discussed, promoted the science learning of young people. Schools also provided informal science learning programmes such as science camps and learning spaces such as school libraries. Government and private companies provided funding to support science learning. Local community institutes and universities offered local learning programmes and events for young people such as science festivals (through universities) and traditional wisdom workshops (through local community institutes). However, the results also showed that family belief in superstition could sometimes limit the personal science learning performances of local young students.

These results will now be considered in the context of the personal, social and physical contexts of Falk and Dierking's (2000) model.

(1) The Personal Context

Falk and Dierking (2000) investigated three personal factors: (1) motivation and expectation, (2) prior knowledge, prior interests, and belief and (3) choice and control in their work on informal science learning. Exploring participants' expectations of Science Caravan engagement indicated that the participants expected to obtain new scientific knowledge and to use this knowledge to promote their formal science learning, rather than expecting to have fun. Particularly, Southern participants expected to gain knowledge and understanding of science, and they also suggested various improvements to the science activities (see Chapter 5, section

5.4.2). Additionally, local teachers expected that the Science Caravan engagement would motivate their students' interest in science learning. Their expectations for the informal science learning activities were mainly that students would learn new knowledge and that students' interest in science learning in school would be stimulated (see Chapter 5, section 5.5). Such expectations have been found in previous work including amongst students visiting a science museum with their school in Lucas's study in 2000, as cited by Eshach (2007), where students expected to learn from a trip rather than to have a 'fun day'. Similarly, Badger and Harker (2016) stated that local students can construct their knowledge and make connections between exhibitions from travelling museums with their real life. In contrast, participants in Kanhadilok's (2013) study who were visiting an informal learning setting such as a museum with their family expected to see interesting things and to enjoy visiting rather than to focus on only learning. The results of this research suggest that students' expectations of informal learning engagement through school, such as engagement with the Science Caravan, are primarily educational, students will expect to see science learning promoted and have their interests in science learning stimulated rather than necessarily to have fun or find it enjoyable.

Regarding prior knowledge, prior interests and beliefs, this research showed that prior knowledge and beliefs affect the science learning of young people, whereas prior interest does not appear to. Low prior knowledge of some participants and limited personal learning performances, such as limited reading and writing skills, inhibited young participants ability to obtain knowledge and understanding from involvement with the informal science learning activities, especially the Northeast participants. These limitations also affected the interest of young participants during their interaction with science activities, as the participants were often unable engage with more difficult activities such as the material science exhibition (see Chapter 7, section 7.2.2 and Chapter 8, section 8.3). In a similar study, Falk and Storksdieck (2005) investigated visitor learning from a science centre exhibition. The researchers mentioned that visitors who had low prior knowledge in life science and lacked a biology background were generally not very interested in the life exhibition, similar to the findings of this research. In terms of beliefs, the results from the teacher interviews suggest that the beliefs of parents or other family members may affect the science learning of children, with a small number of teachers concerned that parents who have a strong belief in superstition are typically against their children learning science and instruct their children to believe in the superstition rather than to investigate scientific knowledge (see Chapter 6 section 6.3.3).

Regarding choice and control factors, Science Caravan engagement provides a somewhat prescriptive order, content and characteristics to the informal science activities offered. For example, participants learned science by following the sequence of the content, by watching the science show, by doing experiments with the science demonstrations and by solving science problems in the science games in a limited time period. However, some areas of the caravan, such as the science exhibitions, including the material and the life science rooms, allowed participants to select which exhibits that they wanted to engage with (see Chapter 7). Overall the Science Caravan was more control oriented rather than choice oriented. The caravan's participants engage with science activities by following NSM staff's suggestions (see the Figure 13 in Chapter 4). Additionally, teachers and friends can be a control factor that can influence decision making around engaging with activities. Similar research has found that visiting specific exhibitions, such as an astronomy exhibition the American Museum of Natural History with others (e.g., friends, family, and peers) can be a control factor in the learning situation of the visitors. For example, in the same group, young members followed older members' suggestion for engaging with activities (Stroud, 2008). However, providing choices that allow visitors to control their own learning is useful in the development of informal learning environments such as museums to promote science learning (Falk and Storksdieck, 2009). Therefore, in offering contexts for both situations the Science Caravan provides instances of both choice and control to its participants.

(2) The social context

With regards to the social context, within-group sociocultural mediation and mediation facilitated by others are two social factors considered by Falk and Dierking's (2000) model. In the Science Caravan, within-group sociocultural mediation occurred among friends and teachers who came from the same school. In the Science Caravan, teachers were the main sources of support and explanation about scientific theory and concepts. Friends also supported science learning and sharing knowledge while interacting with activities in this caravan. Other teachers, students and NSM staff were external social factors, who also promoted the science learning of participants, through observing students and teachers from other schools interacting with activities, and asking NSM staff for explanation about the activities. In an informal learning environment such as a science museum, the internal social group such as family members and friends from the same group influences learning, and adults influence children's interaction with exhibits and activities (Falk and Storksdieck, 2009). In Eshach's (2007) study, while visiting a science museum with a school trip, teachers were supporters that helped students to gain better understanding during students' participation in the exhibition and activities. Similar evidence of social context support was found in this research.

In this research teachers continue to play an important role, they are the key people who have influenced science education, they play a role in the local community, and they offer access to informal science learning program. However, teachers sometimes lacked science skills, confidence or awareness of science and technology or may be unaware of informal science learning spaces, such as the Science Caravan.

Friends were also influential, they can be both promoting and interrupting factors, in some cases they could share knowledge and ideas, in others discussion and strong disagreement between participants impacted on time and learning, as well as their attitude towards the Science Caravan experience in general.

Furthermore, in addition to the family and the school supported informal science learning opportunities for students, this study also found that private companies provided funding to promote science learning, local communities and local universities established informal learning programmes and events, and the government played a role in providing science teachers for local schools, allowing schools to promote science learning more effectively (see Chapter 6 section 6.6.1, 6.6.2 and 6.6.3).

This research found social factors, such as teachers, friends, family, the government, private companies, local universities and local communities, all play a role in the informal science learning of young people at a local level.

(3) The Physical Context

In this research, the Science Caravan as an outreach informal learning programme that was designed to visit students locally is considered as a significant physical context for supporting informal science learning experiences of remote participants. In the Science Caravan, science activities were designed to promote self-learning among the participants whilst, as already discussed, being somewhat controlled and ordered, by timings, NSM staff instruction and scripting. Thus, with the exception of the exhibitions, the physical environment was relatively designed and restricted. In addition, a number of other aspects of the physical context impacted on the experience, including the location of the school, travelling distances, the numbers of students in the physical space preventing access to an activity, the variety of activities possible in the physical space and other facilities to support informal learning.

Therefore, in terms of physical contexts as outreach science program, the time for participation, the number of participants, spaces available at the location, constraints of travelling to a location, and other facilities that were available are also factors influencing learning in informal environments amongst young people.

In summary, factors affecting informal science learning experiences of local young people can defined in three groups based on contextual learning model of Falk and Dierking's (2000)'; personal, social and physical contexts. Personal contexts meant learning performances, prior knowledge and their expectations could be seen to have a relationship. Social contexts meant, in this case, teachers, friends, NSM staff, as well as school, family and other organisations are also factors which effect on young people's informal science learning. Whilst physical contexts, such as location, numbers of participants, other facilities are physical factors found in this research. Falk and Dierking's (2000)'s model has been applied to other previous research such as Kelly (2007); Kanhadilok (2013) and Chang (2006) and these personal, social and physical factors were also factors found in this research.

9.1.3 Question 3; 'How do informal science learning activities meet the needs of different demographic groups?'

The results of this research suggest that informal science learning in the Science Caravan demonstrates two main themes regarding how participants obtained and constructed their knowledge. Firstly, individual interaction and social interaction with informal science activities was apparent and will be discussed. This will use the lens of cognitive construction by individual learning (Wadsworth, 1996; Tryphon and Voneche, 1996) and social constructivism, in regards to examining the development of learners' cognition through social interaction (Van Der Veer, 2007). Secondly, learners' interaction with their most and least preferred science activities was used to investigate the limits and merits of informal activities to improve science learning for different learners. This section will discuss about learning behaviours and the construction of knowledge based on VARK and VEF (Hawk and Shah, 2007; Barriault and Pearson, 2010) (chapter 7 section 7.2 and 7.3) The results from this research found instances of learning in an informal environment that comprised both individual learning and learning by social interaction, in order to obtain and construct scientific knowledge (see Chapter 7 section 7.3).

From the results (see Chapter 7), we can identify that individual learning and social interaction are significant learning process for promoting participants construction of their knowledge. Participants used both individual learning and social interaction to construct their knowledge and expanded that knowledge with instances of ZPD involving teachers, explainers and others supporting participants' learning based on the social constructivism theory of Vygotsky (Daniels, 2008). Moreover, investigating learning behaviours also saw examples from the VARK model (Visual, Audio, Reading and Kinaesthetic) and VEF (initiation, transition and breakthrough behaviours) used for examination as to how participants interacted with exhibitions and activities (Hawk and Shah, 2007; Barriault and Pearson, 2010). These included five main learning behaviours; watching and observing other, exhibitions and activities, performing experiments and activities, sharing knowledge and asking other people, repeating doing activities and experiments, and using experiences to solve the problem. These five learning behaviours combined individual learning and social interaction (see Chapter 7 section 7.3).

This research showed, in terms of individual learning based on cognitive constructivism, participants constructed their knowledge by self-learning. The results of this research indicated that three individual learning behaviours that encouraged participation and the construction of knowledge, were witnessed. This included participants carrying out experiments or activities individually, repeating experiments or activities, and drawing on past personal experiences (for example from school) to solve problems (see Chapter 7 section 7.3).

Learners also constructed their knowledge and understanding from social interaction during their participation in learning activities, such as playing the science games. In this study, participants watched demonstrations of a science experiment and then tried to imitate the actions (see Chapter 7 section 7.3). Additionally, students helped each other to complete a task, worked in teams to solve problems or asked others for help (see Chapter 7 section 7.3).

Moreover, from exploring the most and least popular activities (see Chapter 7 section 7.2), most popular activities amongst students such as the Science Games, Tangram and Science Bingo often promoted self-esteem and self-learning or learning experiences with others by team working or through competition (see Chapter 7 section 7.3). Whereas, those that were less popular, such as the Material Exhibition or the Science Show were seen to be too difficult (see Chapter 7 section 7.3), or dangerous and daunting for them, with some variations amongst age groups (see Chapter 8 section 8.3).

In exploring at the regional level there were differences in how participants wanted to learn, communicated with others, asked questions, and expressed enjoyment. This suggests that considering the different background of participants; particularly age and gender backgrounds, and to some degree by region, may have an influence on the design of science activities in order to meet the needs of participants, and promote their science learning performances.

9.1.4 Question 4; 'What learning and other outcomes do young people obtain from participating in regional informal science activities?'

In investigating outcomes of engagement with science activities in the caravan the Generic Learning Outcomes (GLOs) (Arts Council England, 2017) were applied to examine learning outcomes based on five categories. These categories were developed from the three main learning outcomes, cognitive (knowledge), affective (attitude) and psychomotor (skills), of Bloom's taxonomy (Bloom and Krathwohl, 1956). With the addition of two further categories from the GLOs, category 4; the enjoyment and inspiration domain was split from the affective domain, and creativity was split from the cognitive domain. For category five, this category was different with Bloom's taxonomy, this category focused on changing behaviours and intentions in the future (Brown, 2007).

The research results showed various outcomes of learning in the Science Caravan and these were broader than the initial three main outcomes of Bloom's taxonomy; knowledge, attitude and skills (Bloom and Krathwohl, 1956). There are five categorised outcomes of learning obtained from participating in this regional informal science activity, and these are as follows;

(1) Knowledge and understanding:

The results of this research (see Chapter 8 section 8.2.2) showed participants obtained new scientific knowledge and gained better understanding of how science phenomena are linked with the school curriculum. More than 93% of all participants indicated that 'I found out something I didn't know about science and technology from the science activities in Science Caravan' and more than 90% of all participants mentioned 'I think I will use some knowledge that I obtained from science activities to improve my study in science class'. Hence, visiting informal learning environments such as a travelling museums, and in this case a regional version of it, can increase knowledge and understanding (Badger and Harker, 2016). Local teachers who participated in the Science Caravan also reported obtaining new scientific knowledge and understanding. Though there were no clear trends in regards to learning outcomes at a regional level, there were differences by age and gender, with older participants aged 13-15 and female participants more likely to agree that they wanted to be involved in science activities, to read the instructions, and anticipate that they would use the learning in school.

(2) Skills

The results in Chapter 8 section 8.2.2 suggest that engagement with the Science Caravan can help participants to develop their learning skills. In regards to individual skills, participation in the caravan encourages the practice of experimenting and learning how to use experiment equipment. For example, the Science Caravan has promoted the development of reading skills for high school students and female students more than primary school students and male students, whereas, over 70% of primary school students, and more frequently males, 'found that using scientific methods to find out the answer was difficult for me' (see Chapter 8 section 8.2.1).

The Science Caravan also offers opportunities to develop both communication and social skills by exchanging and discussing knowledge with others, over 80% of participants specified that they ‘talked with friends about how to solve the problem’, and 82.2% of all participants agreed with caravan engagement promoted confidence in expressing their opinions (see Chapter 8 section 8.2.1).

Previous studies have similarly found that informal learning can help students to practice communication skills with adults, abilities and develop learning skills, such as observing, recording and social skills development (Kanhadilok, 2013; Punyain, 2008).

(3) Attitude and values

In attitudes to science activities in the Science Caravan, the results in Chapter 8 section 8.3.2 illustrated that participants generally had a positive attitude in regards to science activities. Participants exhibited higher self-esteem after they participated in science activities and learned by themselves and with others. They had a good attitude towards the NSM staff and the Science Caravan. Similarly, Kanhadilok’s study in 2013 found that participants who engaged with learning science with Thai Toys at NSM had positive attitudes to participating in this activity. Additionally, Triyarat (2011) indicated young participants had positive attitudes to engage with science activities in a Fun Science Room.

Regarding attitudes toward science and technology, the results in Chapter 8 section 8.1 indicated that most participants have positive attitudes towards science technology, with most participants still believing in the benefits and importance of science and technology, including in making life healthier, easier and comfortable, and its importance for the country’s development. There were not obvious trends in regards to the attitude statements at the regional level, and there were no statistical variations in the attitude statements between the age groups, or by gender.

Engagement with the Science Caravan amongst young people may have changed attitudes towards science and technology amongst a few participants (lower than 5% see Appendix C.1-C.10) to become more concerned and disagree with some benefits. However it could be argued that making young people more questioning and aware of scientific developments in general, including their complexity and potential for negative impacts is a favourable aspect of the caravan, regardless.

(4) Enjoyment, inspiration, and creativity

After engaging with the Science Caravan, there was a high sense of agreement that participants had found the activities enjoyable and inspiring. Participants indicated that they enjoyed watching the Science Show, doing experiments with the demonstrator and playing Science Games. In addition, Chapter 8 section 8.2.1 also showed 91.4% of all the participants indicated 'The science activities made me enjoy science more'. Similar results have been found in previous work on informal learning environments (Triyarat, 2011; Punyain, 2008; Kelly, 2007).

As for inspiration, results suggest Science Caravan engagement inspired young participants to consider further study in science and technology, with teachers reporting that engagement can motivate their students to learn more about science and technology, which leads to promoting science learning in school.

Additionally, from the student interview results, engaging with the Science Caravan inspired young participants' wish to be scientists or science communicators in the future (see Chapter 8 section 8.2.2). Moreover, local teachers were also inspired to create new teaching techniques in their classroom after engaging with the Science Caravan.

(5) Activity, behaviour, and progression

In examining activity, behaviour, and progression, this study considered what people do and intend to do (Hooper-Greenhill, 2007). From this study, the results have clearly signified progression of young participants; as already discussed many planned to study more about science and technology topics and/or they wanted to share and do the science experiments with their family. Almost 90% of young people indicated 'I will tell my family and my friends about the importance of science and technology from my caravan visit'.

Investigating learning outcomes based on the GLOs framework allowed the researcher to expand knowledge regarding the learning outcomes of young people who engage with informal science activities beyond the three main categories of learning outcomes encompassed in Bloom's taxonomy (Brown, 2007; Triyarat, 2011 and Kanhadilok, 2013). This included consideration as to how informal science activities encouraged participants to think about the future, and their use of the experience afterwards, with friends, family and in school. Additionally it was able to capture the way in which informal science learning such as that exhibited in the Science Caravan can also promote creativity, and enjoyment, which may additionally contribute to a young person's thinking about the potential for a science career. However, Bloom's taxonomy is a fundamental framework that has been used to explore the learning development of learners based on cognitive, affective and psychomotor, for example, Punyain's (2008) study in Thailand used Bloom's framework to study the construction of knowledge of young participants who visited Chaingmai Zoo in 2008, though this also recognised the need to expand beyond the three main categories.

In this research, involvement with informal science learning encouraged participants to obtain knowledge and understanding; skills; attitudes and values; enjoyment, inspiration, and creativity; activity, behaviour, and progression.

9.2 Promoting the development of the science caravan and other informal science communication projects at the regional level in future

The results of discussion in the first four research questions are considered for responding to research question 5; *'How can this learning be applied to other informal science communication projects at the regional level?'* to promote the development of informal science learning activities at a regional level. There are three main suggestions presented in this section which pertain to underserved people, the future of the Science Caravan and implications for other regional informal learning activities.

9.2.1 Underserved Thai people and informal science learning

This research suggests there is capacity to increase informal science learning opportunities for underserved people in Thailand, such as the young local participants that were engaged here, in particular as similar activities often lack availability or access opportunities for people who live at a distance. The results in relation to scientific knowledge before and after participation in the caravan showed over 50% of participants had higher scores after engagement with the caravan (see Chapter 7 section 7.1), and this was especially the case amongst the northeast participants who had highest percentage of participants who had a science test score increase after involvement in informal science activities at 58% (N=203) amongst the 350 northeast participants. This is notable as the northeast is recognised as being one of the key underserved regional locations in Thailand (Tumtong, 2014).

Similarly, Badger and Harker's (2016) study, found that a travelling science museum could have an influence on remote and poor students in the US. This investigation illustrated that a visiting travelling science museum promoted underserved students to obtain a better understanding of science and that they can make real-life connections with school curriculums. Additionally, this study indicated remote teachers also have a low estimation of their ability and the visiting travelling science museum was also able to encourage teachers to develop their teaching abilities to support science learning and teaching in school. Similar results from teachers were found in this research, whereby involvement in informal science learning activities inspired them to develop their science teaching. They found many ideas about teaching science techniques and they also obtained new scientific knowledge from informal science learning engagement (see Chapter 8 section 8.2.2).

Travelling science museums or outreach science programs can therefore support underserved participants who have low-incomes or are living far away informal learning institutes, offering them more opportunities to engage with informal science learning. Matson and DeLoach (2004) created an outreach science programme; the Robot Roadshow Program for rural and underserved schools in the US. This programme helped underserved students in K-12 obtained better understanding of science and math from interacting with robots, and also encouraged they have more interested in science and technology within robots. The results in this research, also suggest local participants were more likely to indicate that they hoped to engage with informal science learning activities again, to use their learning in school and to understand science and technologies relationship to their everyday lives. Informal science learning activities, such as travelling science museums or outreach science programmes, can therefore be helpful in supporting underserved people to have opportunities to engage with informal science learning activities.

9.2.2 The development of the Science Caravan in the future

The first suggestion is that the Science Caravan has areas which can continue to be developed for future participants. The results regarding the limitations of learning in the Science Caravan and the needs of participants (see Chapter 8, section 8.3.1 and 8.3.2) can be used directly to support the development of the Science Caravan activity in the future. For example, the identified limitations included the number of participants, time for involvement with activities, unclear information on the exhibits' labels and limited personal learning skills; knowing these limitations is useful to promote further improvement of the Science Caravan. Additionally, the needs of participants from the Science Caravan were identified as including regular, annual visits, a higher number of activities (e.g., developing activities to support different skills and learner needs), more new activities, longer time periods for engagement with activities, and simpler language for scientific explanations. Understanding these needs can in turn help promote the development of the Science Caravan.

Additionally, the learning outcomes identified in this research, and those outcomes' relationship with participants' expectation can also be used to further tailor the development of informal science activities which meet participants' expectations. For example, at a regional level, most local northeast and northern participants interacted with science activities without reading instruction. They may lack the opportunity to obtain new knowledge from the activities instructions and they may learn to interact with exhibits in the wrong way. The development of label instruction for easier reading and understanding, or additional guidance that it is a good idea to read the labelling, may support participants from both of regions gain new knowledge and better understanding. Knowledge about the learning behaviours and processes of knowledge construction of different participants can be used to support the design of informal science activities for different participants and in different types of regional settings.

9.2.3 Applying the research to the development of other informal learning projects

The research results indicate that considering the factors of informal learning—namely the characteristics of informal learning activities, local participants' construction of knowledge and outcomes of learning—will promote the development of informal learning activities that meet the needs of local participants. For example, the science show encouraged one primary student's interest in scientific knowledge, while the same student found the material science exhibitions to be too difficult to understand. Activities' designs may better consider the differences in participants' demographics, prior knowledge and interests, ways of obtaining knowledge, and outcomes of learning.

These results can also be applied to other informal learning projects in terms of exploring the factors which promote learning and those which are seen to obstruct. This knowledge can be used to promote activities and generate new designs, ultimately providing activities and environments that encourage teachers to support their students' learning in informal learning environments and learning materials that promote self-learning to develop personal learning skills and performance, e.g., different activities that promote learning in different participants with different backgrounds, prior knowledge, interests and expectations.

The results on the informal learning resources available for local young people, namely the public libraries and the school libraries, highlighted the importance of easy and free access for local people. However, these libraries can have limited and out-of-date learning materials. To promote local people's learning, especially the learning of young people in remote areas, this research result suggests the development of resources for public and school libraries, including online technology may be beneficial.

This research knowledge can be used for promoting the Science Caravan development directly and also applied to promote other informal learning projects.

Chapter summary

The discussion of first four research questions offer a significant investigation of the factors affecting engagement with informal science learning of local young people in Thailand. In informal learning contexts, there are three main significant physical, personal and social contexts based on Falk and Dierking (2000) which were identified in the research results. Physical contexts including public and school libraries, as well as the internet offer opportunities for informal science learning for students based throughout Thailand. In regards to the personal context, participants' expectations, limits of prior knowledge and learning skills, and choice and control of learning in informal environments all affected participant's informal learning experiences within the Science Caravan. At the level of social context, teachers are the key people who promote learning science in school and signpost informal learning environments. Whilst in terms of the construction of knowledge, individual learning and social interaction are two main factors that promote the expansion of participants' knowledge, and both of factors also support each other to help participants obtain knowledge and understanding, opportunities for practicing learning and social skills, enjoyment, positive attitude to science, and planning for future education and science careers. Finally, this chapter illustrated how to the research knowledge could be applied to develop other informal science communication projects at the regional level.

Chapter 10

Conclusion and Implications

Overview

This research investigated the factors affecting engagement with informal science learning amongst young people in Thailand. The study examined the informal science learning settings and resources that are available to young people in different regions of Thailand, the main factors affecting informal science learning experiences, the construction of knowledge amongst different learners, the learning outcomes following participation in regional informal science activities, and the ways in which the research could be applied to other informal science communication projects at the regional level. This chapter provides a conclusion that summarises and assesses the key research results, the limitations of this study and the implications of the findings for informal science learning and communication and additionally proposes a new informal learning model based on informal learning contexts, knowledge construction and outcomes of learning is proposed. The chapter recommends expanding the investigation of informal science learning's effects by examining different groups of participants and different informal learning resources. Finally, the chapter considers how this research can promote and inform future study.

10.1 Conclusions: Research questions and findings

This section presents the conclusions drawn in response to the research questions.

Question 1: What settings or resources are available to young people for informal science learning at the regional level?

Public and school libraries are significant informal learning resources at a regional level. They offer learning materials such as science books, multimedia documentaries and computers with internet access. Moreover, the Internet is often used to access scientific knowledge and information and thereby to promote science learning in schools. However, public and school libraries are unable to fully meet young people's demands. Availability of free access to computers with the internet through libraries or local communities' services is also limited. Hence, the Science

Caravan provides another important opportunity for some young people to access informal science learning opportunities.

Question 2: What are the main factors affecting the experiences of Thai young people in informal science learning?

Based on Falk and Dierking's (2000) learning model, personal, social and physical factors were considered. Personal learning performance, prior knowledge, expectation and motivation, including choice and control, were the key factors identified as affecting young people's science learning. The social factors identified were teachers, friends, family, government, private companies, local universities and local communities, all of which can be promoters of young people's learning in informal environments.

Question 3: How do informal science learning activities meet the needs of different demographic groups?

The construction of knowledge during involvement with informal science activities was considered based on theories of cognitive and social constructivism, including VARK and VEF. Local participants obtained and constructed their knowledge as individuals by interacting independently with activities such as science exhibits in the science exhibitions room by following the instructions on the exhibit label. Participants constructed their knowledge and understanding via social interaction by asking about, sharing and discussing science content with other participants, teachers and explainers.

Question 4: What learning and other outcomes do young people obtain from participating in regional informal science activities?

Five learning outcomes based on the Generic Learning Outcomes (GLOs) (Arts Council England, 2017) were identified after participants' engagement in the Science Caravan. Most participants indicated that they had obtained scientific knowledge and understanding. They also expressed that they had enjoyed the experience and developed a positive attitude toward informal science learning activities. Participants had developed their learning skills such as scientific method skills and social and communication skills. They also planned to study more about the topics that they had learned about from the caravan and to do experiments with their family and friends.

Question 5: How can this learning be applied to other informal science communication projects at the regional level?

The research results indicated that informal science learning such as the Science Caravan engagement provides opportunities to support science learning amongst underserved participants such as the local young people who have limited opportunities to involve with informal science learning and limited science teaching within school.

This study indicated limits in existing informal science activities related to the needs of different participants. This knowledge can be applied to support the development of informal science learning activities at the regional level. For example, the needs of different learners, for instance female and male participants may require different learning methods to help in knowledge acquisition and understanding from the informal learning events.

Furthermore, understanding the needs of participants also assists in the development of informal learning activities. For example, primary school students may need longer time to engage with activities in order to obtain knowledge and better understanding, whereas high school students may need less time.

This research can promote the development of Science Caravan in the future and can inform the development of other projects that respond to the specific needs and characteristics of local young people. In particular, the study of the contextual learning, knowledge construction processes and outcomes from engagement with the Science Caravan can be applied to investigate other regional informal learning projects. Regional informal learning projects can be better designed and assessed by applying knowledge of the three main factors affecting science learning; contexts of learning, construction of knowledge and outcome of learning. For example, exploring learning outcomes promotes awareness of the purposes in creating informal learning projects. Understanding the construction of knowledge based on constructivism theory can encourage activities designed for different learners, such as learners who prefer learning by oneself or learning with others.

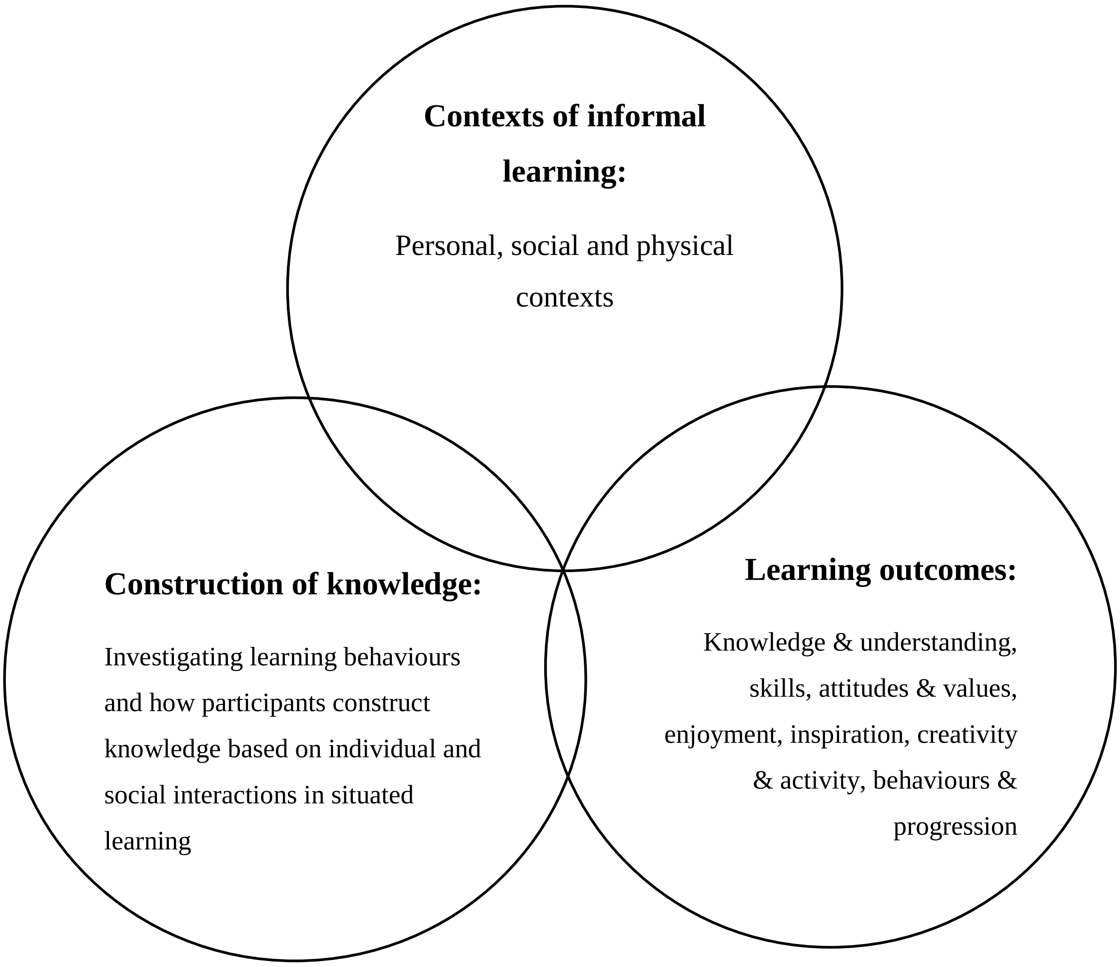
10.2 The CCL model (Context of Informal Learning, Construction of Knowledge and Learning Outcome)

This research suggests that factors for the proposed informal learning model were generated from investigating three main areas: (1) contexts of informal learning based on a contextual learning model composed of three features: personal, social and physical contexts (Falk and Dierking, 2000), (2) construction of knowledge based on constructivism theory (Stroud, 2008), and (3) outcomes of participation in informal learning activities based on the Generic Learning Outcomes (GLOs) (Arts Council England, 2017) and proposes the use of the CCL model to investigate factors affecting the informal science learning.

The informal learning model developed from this research can support investigation into the factors that affect informal learning with different audiences and informal learning spaces at different levels. The model could, for example, be applied to investigate the informal learning of other groups, such as urban young people, or to examine local informal learning spaces, such as public libraries, to develop these spaces to better support learning amongst their users and also to better meet the needs of these audiences.

From this study, three main factors were found to affect the informal science learning: the context of the informal learning, the construction of knowledge and the learning outcomes and this comprises the CCL model (see Figure 71).

Figure 71: The CCL model (Contexts of Informal Learning, Construction of Knowledge, and Learning Outcomes)



Using this model to investigate informal learning environments could further improve informal learning activities and facilitate the design of environments that meet the needs of participants. The model could be used to examine the factors affecting the informal learning environment of specific types of participants, over different regions and in different national settings. The factors defined in the informal learning model are important parts of the process of effectively improving and developing informal learning activities.

10.3 Applying the research to other regional informal science communication projects

The research results indicated that informal science learning such as the Science Caravan engagement provides opportunities to support science learning amongst underserved participants such as the local young people who have limited opportunities to involve with informal science learning and limited science teaching within school.

This study indicated limits in existing informal science activities related to the needs of different participants. This knowledge can be applied to support the development of informal science learning activities at the regional level. For example, the needs of different learners, for example female and male participants may require different learning methods to help in knowledge acquisition and understanding from the informal learning events.

Furthermore, understanding the needs of participants also assists in the development of informal learning activities. For example, primary school students may need longer time to engage with activities in order to obtain knowledge and better understanding, whereas high school students may need less time.

This research can promote the development of Science Caravan in the future and can inform the development of other projects that respond to the specific needs and characteristics of local young people. In particular, the study of the contextual learning, knowledge construction processes and outcomes from engagement with the Science Caravan, captured by the CCL model, can be applied to investigate other regional informal learning projects. Regional informal learning projects can be better designed and assessed by applying knowledge of the three main factors affecting science learning; contexts of learning, construction of knowledge and outcome of learning. For example, exploring learning outcomes promotes awareness of the purposes in creating informal learning projects. Understanding the construction of knowledge based on constructivism theory can encourage activities designed for different learners, such as learners who prefer learning by oneself or learning with others.

10.4 Limitations and implications

This section provides a reflection on the overall limitations which emerged in the context of this research investigation. The prior sections have discussed how the research knowledge could be applied to promote and improve other regional projects' development in the future. However, several limitations need to be considered in any future research. These are limitations in three areas: research design and methodology; data collection, research samples and informal learning activities are considered.

10.4.1 Limited time for data collection

This research collected the data via pre- and post-questionnaire and via interview after participation in the Science Caravan. Due to the limited time for data collection, all of the post data were collected immediately after participation. The results of investigating changes in attitude towards science, background scientific knowledge and learning outcomes were thus reflected in the participants' responses immediately after finishing the activities. Monitoring how science activities engagement influences the science learning of participants in the long term should also be considered. Such a future study could explore the impact of informal science learning engagement after six months or one year on young people's science learning. This research could monitor changes in attitude towards science, scientific knowledge, promotion of science learning in school and other outcomes, particularly as the Science Caravan can make repeat visits to the same locations or schools. Such a study would be useful research to promote understanding of how informal science learning engagement impacts on the long-term science learning of young people.

10.4.2 Limited research participants

Participants in the Science Caravan were the focus of this investigation. The results of this study were therefore representative only of the young people engaging with informal science learning activities in the Science Caravan. Many potential people participate in informal science learning activities such as the Science Caravan, including young people in the main cities who engage with the Science Caravan through a school trip. A study of young people in urban areas would promote better understanding of the characteristics of urban participants and how they obtain and construct their knowledge from the Science Caravan engagement and how this may differ from those based at the regional level. A study of the differences between urban and regional groups' engagement with the Science Caravan may fill the gap of investigating the impacts of informal science learning activities on different participants' science learning. Moreover, focusing on young people who visit outreach programmes such as the Science Caravan independent of their school may fill the gap of understanding how engaging in the Science Caravan via a family excursion compared with a school trip influences the informal learning of young people. A study of participation in other types of informal science learning opportunities available would also fill a gap in knowledge regarding opportunities for informal science learning in Thailand and similar geographical and environmental settings (Punyain, 2008 and Kanhadilok, 2013).

10.4.3 Limited engagement of participants with informal science learning activities

This research investigated local young people who engaged with the small-scale Science Caravan. In the small-scale version, the NSM staff designed how participants engaged with activities. Participants were controlled by being guided along a set route of involvement that encouraged participants to engage with all five main activities, namely the Science Show, Science Demonstration, Science Games, Science of Material Exhibition and Science of Life Exhibition (see Chapter 4 section 4.3). Therefore, this investigation represented informal science learning of young people in a controlled environment in which the NSM staff led the participants. This investigation did not address how participants interact with informal learning activities, construct their knowledge and understanding, and generate learning outcomes during free engagement that offers participants choices for learning and control over how they learn.

In addition, the researcher is also an NSM staff member, which may have conflicted with the participants' responses during data collection. For example, some participants may have not have given a full critique about the project directly, and some NSM staff interviewees may have found it difficult to answer some interview questions due to the 'power distance' between NSM and the research participants may conflict the NSM staff member's ability to express their views (Kamolpattana , 2016).

On top of this, there were difficulties for participants responding to the questionnaires. For example, primary school students may have found some questions, more particularly the attitudes toward science section, difficult to understand. Time and participants' background may, therefore, have influenced their reply or affected the accuracy of some responses. Further assistance from the researcher could help clarify questions, which is important in effective data collection.

10.5 Implications for practice

This section discusses the implications of the research findings in three main areas; the development of sustainable science learning for young people, the development of informal science learning activities or settings and the development of informal learning resources.

10.5.1 Sustainable science learning of local young people

In this research, it was apparent that the internet and Wi-Fi were increasingly important resources for young people. Smartphones, Internet Cafés, and home computers were used to access scientific information by young people in remote areas. To promote sustainable science learning in local communities, providing scientific knowledge on websites and additional online resources after Science Caravan engagement offer opportunities for young people to continue their science learning and engagement, as well as offering additional sources for teachers. This may help to develop a wider sense of the role of science in local communities.

10.5.2 The development of informal science learning activities or settings

The development of informal science learning opportunities must take into consideration participants' learning behaviours (see Chapter 7 section 7.3), observed learning outcomes (see Chapter 8 section 8.2), limitations of engagement (see Chapter 8 section 8.3.1) and needs (see Chapter 8 section 8.3.2). The results suggest that sufficient dwell time and varied activities are important for promoting learning amongst different participants. For example, primary school students needed more time to learn the science in the Material Exhibition, whereas high school students needed more science experiments designed to support their school curricula. Additionally, enjoyment of an informal learning environment is important for encouraging participants to obtain knowledge and understanding from engagement such as that included within the Science Caravan. Providing a clearer instruction for hands-on exhibit can support individual-learning in an informal learning environment. Investigating how different participants obtain and construct their knowledge enables development of different activities that will facilitate learning for different participants. Finally, taking the learning outcomes from the Science Caravan into consideration can better define the purpose of informal science learning engagement and enhance participants' science learning.

10.5.3 The development of the informal learning resources

The results of this research suggest that public and school libraries and the internet are important informal science learning resources for young people in Thailand. However, some public and school libraries have limited learning materials and young people may have limited access to internet services because of the high cost of equipment and connection charges. Travelling to informal science centres could, therefore, be a significant informal learning resource for local young people. Increasing the number of locations that the Science Caravan visits in remote areas could facilitate science learning for more young people, as could development of other travelling science learning programmes. Similarly, providing learning materials such as books, science media, and computers and internet resources for public and school libraries may promote and extend the science learning of local young people.

10.6 Recommendations for future research

Based on the findings of this study, future studies could be focused on the development of a standard tool, based around the CCL model, for investigating factors affecting learning in informal learning environments. In developing a standard tool for investigation, the three main factors affecting informal learning found through this research were; the contexts of informal learning, the construction of knowledge, and learning outcomes. These factors could be applied to a tool designed to investigate different groups of participants, other informal learning settings and activities, and at other geographical levels such as urban, national and international level. These would significantly benefit this area of research.

At the international level, this tool could be used to explore participants' engagement with informal science learning activities in different countries. For example, Laos's participants who engaged with the Science Caravan of the NSM could be investigated. Such a study could examine the differences between Laos and Thai participants' informal science learning experiences from engaging with Science Caravan. This study could lead to understanding of the factors affecting informal science learning in the different country contexts. Furthermore, the knowledge obtained could in turn inform development of informal learning activities to stimulate informal science learning in both countries.

The development of such a proposed tool could build up investigations of learning in informal learning environments, allow for a greater welcoming of different types of participants and offering different informal learning activities or settings at different levels.

10.7 Final words

This investigation has produced new and original results regarding the factors affecting the engagement of local young people in Thailand with informal science learning. The implications of this research extend far beyond the single group of participants and the single regional informal science learning environment investigated (i.e., the Science Caravan). The implications are relevant to other contexts, other participants and other informal science learning activities.

The results and discussion of the factors in this research deepen understanding of engagement with informal science learning in general. The major contributions of this study have been in analysing the experiences of local young participants engaged with the informal science learning activities in the Science Caravan. Three significant factors studied in this research were examined to develop responses to the five research questions: contexts of informal learning, knowledge construction and learning outcome. These factors were drawn from Falk and Dierking's (2000) contextual learning model, from the constructivist theory of learning, and from the Generic Learning Outcomes (GLOs) (Arts Council England, 2017). These three significant factors of informal learning can apply to investigations in other contexts, especially to investigations of other local informal learning settings and different participants such as urban young people, to expand the knowledge to cover all young participants in Thailand.

Moreover, the development of the CCL model for investigating the factors affecting informal learning involvement was based on three contexts in this research: contexts of informal learning, knowledge construction and learning outcomes. Therefore this tool will be useful in examining factors affecting engagement with informal science learning at the international level, such as factors affecting the informal science learning of young people in other countries and contexts.

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Appendices

Appendix A

Data collection tool

A.1: The pilot study pre questionnaire

UWE University of the West of England BRISTOL

Participant No. : ……………..………
Date: .... **Time:** ………..
Location/town: ………………….
Region: …………………………...
(For staff)

Pre-Questionnaire (Pilot study)

Developing a Regional Framework for Science Communication Activities in Thailand

This survey is being conducted by Wilasinee Triyarat, as part of PhD research in Science Communication, at University of the West of England, Bristol (UK). The aim of the research is to investigate science communication activities that are occurring at a regional level in Thailand. Participation is voluntary. By completing this survey you are giving your consent for use the data collected. The information will only be used for academic purpose, and your answer will remain anonymous. You are free to withdraw without having to explain your reasons before the 30th September 2015. Completing this questionnaire should take no more than 15 minutes of your time. You will be asked to complete another one once you have participated in the activities to measure any changes in knowledge, and to get your feedback on the science activities.

Nickname: ……………………………..… **Date of Birth:** ……………………..……………….……
School: …………………………………… **Grade:** …………….…………….…………....…..….…..…

Demography

1. Age: ……………………...
2. Gender: ☐ Male ☐ Female
3. What is your nationality? ……………………….
4. Religion: ☐ Buddhist ☐ Christian ☐ Roman Catholic ☐ Hindu ☐ Sikh
   ☐ No religion ☐ Prefer not to state ☐ Other …………………………..
5. Who is your current parent/carer?
   ☐ Father and Mother, please answer Q. 6 to Q.19
   ☐ Father, please answer Q.6 and Q.7
   ☐ Mother, please answer Q.8 and Q.9
   ☐ Other ………………………………., please answer Q.10 and Q.11
6. What is your father's current occupation?
   ☐ Scientist ☐ Nurse ☐ Doctor ☐ Police/Soldier ☐ Engineer
   ☐ Government officer ☐ Private company ☐ Part-time staff
   ☐ Farmer/agriculturist ☐ Other …………..
7. What is your father's highest level of education?
   ☐ Below Bachelor Degree ☐ Bachelor Degree or equivalent ☐ Master Degree
   ☐ PhD/Doctoral ☐ Other ………………………………………………….

8. What is your mother current occupation?

 Scientist Nurse Doctor Police/Soldier Engineer

 Government officer Private company Part-time staff

 Farmer/agriculturist Other ………………………………………………

9. What is your mother's highest level of education?

 Below Bachelor Degree Bachelor Degree or equivalent Master Degree

 PhD/Doctoral Other ……………………………………………….

10. What is your carer's current occupation?

 Scientist Nurse Doctor Police/Soldier Engineer

 Government officer Private company Part-time staff

 Farmer/agriculturist Other …………………………………………………

11. What is your carer's highest level of education?

 Below Bachelor Degree Bachelor Degree or equivalent Master Degree

 PhD/Doctoral Other ……………………………………………….

12. What is your parents/carers religion?

 Buddhist Christian Roman Catholic Hindu Sikh

 No religion Prefer not to state other ……………………………..

13. Province/town of your current address: ………………………………………………

Interest and involvement in science

14. Outside school, where, if anywhere, have you heard or read about science and technology last month?

(Please select **<u>no more than three answers</u>**)

 Book From scientists themselves Friends or family Parent

 Films Magazines Museums or Science and Discovery Centre

 Print newspapers Radio Science blogs other internet websites (not science blog)

 TV news Other TV programmes (not news) don't know

 None of these Other ……………………………………………….

15. What is the main media you use to get most of your information about science and technology? (please select only **<u>one</u>** answer)

 Book From scientists themselves Friends or family Parent

 Films Magazines Museums or Science and Discovery Centre

 Print newspapers Radio Science blogs other internet websites (not science blog)

 TV news Other TV programmes (not news) don't know

 None of these Other ……………………………………………….

Attitude towards science and technology

16. This section explores your perspectives on science and technology. Please tell us how much you agree or disagree with each statement.

No.	Statement	Strongly Agree	Agree	Disagree	Strong Disagree
16.1	Science and technology make our lives healthier, easier and more comfortable.				
16.2	The application of science and technologies will make people's work more interesting.				
16.3	Science and technology make our way of life change too fast				
16.4	We should follow up the progress of the advanced science and technology. Although, we will not be scientist.				
16.5	Science and technology are relevant to everyday life.				
16.6	People obtain the great benefits from science and technology more than harmful effects.				
16.7	Science and technology has important to the development of our great country.				
16.8	Science and technology can sometime damage people's moral sense.				
16.9	Thai people trust the superstition too much. Therefore, we should use science and technology to solve this problem.				
16.10	Science and technology research should be supported by government even if it brings on obvious immediate benefits.				

17. In your opinion, please tell me about the relevance of science and technology on your life.

Science knowledge background

18. This section will explore your science knowledge background in general. These questions were designed by National Statistic Office, Thailand in 2008. Please answer the questions.

No.	Question	Agree	Disagree
18.1	Vitamin C can help prevent or even treat colds.		
18.2	We can float better in freshwater than in sea water.		
18.3	Jatropha is the name of the type of oil.		
18.4	Rock salt does not contain iodine		

18.5	Fish breathe through fins.		
18.6	The Earth's core is very hot		
18.7	Radioactivity is man-made radiation.		
18.8	Father's genes determine baby's sex		
18.9	Laser caused by the combination of the sound waves.		
18.10	An electron has less mass than an atom.		
18.11	Antibiotics can kill viruses as well as bacteria.		
18.12	The continents are moving all the time for several million years, and these plates will be moving in the future.		
18.13	Early humans lived at the same time as dinosaurs.		
18.14	The earth rotates or revolve around the sun in one year		
18.15	Global warming is the change from winter to summer.		
18.16	GMO is the music production company.		
18.17	Nanotechnology is cosmetics from Japan.		
18.18	Cloning is the cleaning face by a mud mask for beautiful skin.		
18.19	Gasohol is gasoline mixed with ethyl alcohol.		
18.20	Electronic Commerce is trading of the electronic products.		

Science Caravan

19. Have your heard about the Science Caravan Project before today?

 Yes, I have No, I haven't

20. If you heard about this project, where have you heard this project? (Please select no more than three answers)

 School/ University Local radio station Newspaper Magazine/ Journal

 National Science Museum, Thailand's website TV Leaflet

 Other …………………………………………………………….

21. Have you ever been involved in science activities of Science Caravan Project before today?

 Yes, I have No, I haven't

22. If yes, when did you last participate in Science Caravan?

 Last year Two years ago Three years ago other ………………………….

After you complete your participation in science activity, please do another questionnaire for the post-test.

Thank you very much for your participation in this evaluation

A.2: The pilot study post questionnaire

University of the West of England BRISTOL	**Participant No. :** …………..……… **Date:** .... **Time:** ……….. **Location/town:** …………………. **Region:** …………………………... (For staff)

Post-Questionnaire (Pilot study)

Developing a Regional Framework for Science Communication Activities in Thailand

This survey is being conducted by Wilasinee Triyarat, as part of PhD research in Science Communication, at University of the West of England, Bristol (UK). The aim of the research is to investigate science communication activities that are occurring at a regional level in Thailand. Participation is voluntary. By completing this survey you are giving your consent for use the data collected. The information will only be used for academic purpose, and your answer will remain anonymous. You are free to withdraw without having to explain your reasons before the 30th September 2015. Completing this questionnaire should take no more than 15 minutes of your time. You will be asked to complete another one once you have participated in the activities to measure any changes in knowledge, and to get your feedback on the science activities.

Nickname: ……………………………..…	**Date of Birth:** …………………………………
School: ……………………………………	**Grade:** ……………….……………..……..…….….

Attitude towards science and technology

1. This section explores your perspectives on science and technology. Please tell us how much you agree or disagree with each statement.

No.	Statement	Strongly Agree	Agree	Disagree	Strong Disagree
1.1	Science and technology make our lives healthier, easier and more comfortable.				
1.2	The application of science and technologies will make people’s work more interesting.				
1.3	Science and technology make our way of life change too fast				
1.4	We should follow up the progress of the advanced science and technology. Although, we will not be scientist.				
1.5	Science and technology are relevant to everyday life.				
1.6	People obtain the great benefits from science and technology more than harmful effects.				

1.7	Science and technology has important to the development of our great country.				
1.8	Science and technology can sometime damage people's moral sense.				
1.9	Thai people trust the superstition too much. Therefore, we should use science and technology to solve this problem.				
1.10	Science and technology research should be supported by government even if it brings on obvious immediate benefits.				

Science knowledge background

2. This section will explore your science knowledge background in general. These questions were designed by National Statistic Office, Thailand in 2008. Please answer the questions.

No.	**Question**	**Agree**	**Disagree**
2.1	Vitamin C can help prevent or even treat colds.		
2.2	We can float better in freshwater than in sea water.		
2.3	Jatropha is the name of the type of oil.		
2.4	Rock salt does not contain iodine		
2.5	Fish breathe through fins.		
2.6	The Earth's core is very hot		
2.7	Radioactivity is man-made radiation.		
2.8	Father's genes determine baby's sex		
2.9	Laser caused by the combination of the sound waves.		
2.10	An electron has less mass than an atom.		
2.11	Antibiotics can kill viruses as well as bacteria.		
2.12	The continents are moving all the time for several million years, and these plates will be moving in the future.		
2.13	Early humans lived at the same time as dinosaurs.		
2.14	The earth rotates or revolve around the sun in one year		
2.15	Global warming is the change from winter to summer.		
2.16	GMO is the music production company.		
2.17	Nanotechnology is cosmetics from Japan.		
2.18	Cloning is the cleaning face by a mud mask for beautiful skin.		
2.19	Gasohol is gasoline mixed with ethyl alcohol.		
2.20	Electronic Commerce is trading of the electronic products.		

Experiences in Science Caravan

3. Which science activity were you involved in today?

   □ Puzzling Things (mobile exhibition) □ Science Experiment □ Science Show

4. If you attended more than one activity, which was your favourite science activity for today?

   □ Puzzling Things (mobile exhibition) □ Science Experiment □ Science Show

5. Please tell me why?

Learning outcome and perception of learning science with science activity

6. This section explores the outcome of participation in Science Caravan's activities. Please tell us how much you agree or disagree.

No.	Statement	Strongly Agree	Agree	Disagree	Strong Disagree
6.1	I found out something I didn't know about science and technology from science activities in Science Caravan.				
6.2	I learnt that science cannot provide perfect answers to problems.				
6.3	I learnt science facts in daily life from science activities.				
6.4	I could make sense of most of things that I saw and I did at Science Caravan.				
6.5	I understand and know how to interact with activities by reading the instruction from a panel or a manual.				
6.6	I talk with friends about how to solve the problem.				
6.7	It is okay for me to express my opinion.				
6.8	I know how to use science equipment.				
6.9	I feel happy when I interact with science activity.				
6.10	I think I don't want to be involved with science activities outside classroom.				
6.11	I think learning science from activities is a drag.				
6.12	I enjoyed using scientific methods to find out the answer.				
6.13	The science activities made me like science more.				
6.14	These activities made me understand science better.				
6.15	Participation in science activities was a good chance to learn science in easy way.				
6.16	Learning science in Science Caravan made me know more about scientific theories.				

6.17	I will tell my family and my friends about the importance of science and technology.				
6.18	I will use science experiment to solve science problems in everyday life.				
6.19	I think I will use some knowledge that I obtained from science activities to improve my study in science class.				
6.20	I think the science and technology news are important for my life. I should follow their news.				

7. In your opinion, please tell me more about your experience of science from attendance at the Science Caravan Project.

8. In your view, please tell me about the relevance between the Science Caravan and regional opportunities in science.

9. In your perception, please tell me about the relevance between the Science Caravan and Social belief.

10. In your opinion, please suggest us about how to encourage you involve with this project again?

11. Is there anything you would like to add? Please tell us.

Thank you very much for your participation in this evaluation

A.3: The observation sheet

University of the West of England
BRISTOL

Observation sheet (Field note observation)

Developing a Regional Framework for Science Communication Activities in Thailand

<table>
<tr><td colspan="3">Science Activity: ……………………………………………………………………………………...……</td></tr>
<tr><td>Participant Number: ………..
Age: ……. Gender: ……..…
Observer: ……….…………...</td><td>Date.……………..…….….…….
…..
Time in: …….. Time out:
…………
Total time spent in area:
………..…</td><td>Location: ……..………..…
Town: ……….…….….……
Region: ………………….</td></tr>
<tr><td colspan="3"></td></tr>
</table>

A condition of activity setting was….

- ☐ **Very busy**
- ☐ **Fairly busy**
- ☐ **Quiet**
- ☐ **Very quiet**

What they do based on the Visitor Engagement Framework (VEF) in three main behaviours.

1.Initiation behaviours
- Doing the activity
- Spending time watching others engaging in activity or observing the exhibit

2.Transition behaviours
- Repeating the activity
- Expressing positive emotional response in reaction to engaging in activity

3.Breakthrough behaviours
- Referring to past experiences while engaging in the activity
- Seeking and sharing information
- Engaged and Involved: testing variables, making comparisons, using information gained from activity

Specific point to look for

- How do participants interact with activity?
- Do they concentrate with activity…. (How)?
- Do they interest in speaker/staff/demonstrator's explanation…. (How)?
- Do them answer/response speaker/staff/demonstrator… (How)?
- Do they notice… (How)?
- Do they try to do/ solve a problem/ find out the answer… (How)?
- How long does it hold their attention?
- Do they look happy, bored, engaged, distracted… (How)?
- Do they interact with other people… (How)?
- Who take the lead?
- What other problems do they encounter?
- Overall what is their reaction to science activity?

****This sheet is designed to record participant's behaviour by describing detail during they spent time with activity. The observer has to note carefully.****

A.4: The pre questionnaire

UWE BRISTOL University of the West of England

Participant No. : ……………..……….
Date: .... **Time:** ……………..
Location/town: ……………………..
Region: …………………….……….
(For staff)

Pre Questionnaire

Developing a Regional Framework for Science Communication Activities in Thailand

I am Wilasinee Triyarat. I am a PhD student in Science Communication, at University of the West of England, Bristol (UK). I want to know about your interest and learning about science. I will use your answers for my studies and your answer will not be connected back to you. If you do not want me to use your information you can ask your teacher to contact me, and I will withdraw your information. Please tell then before the 30th September 2014. The questions will take about and please complete post questionnaire after you finish all activities in Science Caravan – Red Route.

Nickname: ……………………………… **Date of Birth:** …………………………………………
School: …………………….………… **Grade:** …………………..………………..……..……...

Demography

1. How old are you?……………………...
2. Are you? ☐ Male ☐ Female
3. What is your religion?

   ☐ Buddhist ☐ Christian ☐ Roman Catholic ☐ Hindu ☐ Sikh

   ☐ No religion ☐ Prefer not to state ☐ Other

   ……………………………………………..
4. Who is your current parent/carer?

   ☐ Father and Mother, please answer Q. 5 to Q.8

   ☐ Father, please answer Q.5 and Q.6

   ☐ Mother, please answer Q.7 and Q.8

   ☐ Other ………………………………., please answer Q.9 and Q.10
5. What is your father's current occupation?

   ☐ Scientist ☐ Nurse ☐ Doctor ☐ Police/Soldier ☐ Engineer

   ☐ Teacher ☐ Government officer ☐ Private company ☐ Part-time staff

   ☐ Farmer/agriculturist ☐ Other ………………………………
6. What is your father's highest level of education?

   ☐ Below Bachelor Degree ☐ Bachelor Degree or equivalent ☐ Master Degree

   ☐ PhD/Doctoral ☐ Illiterate
7. What is your mother current occupation?

   ☐ Scientist ☐ Nurse ☐ Doctor ☐ Police/Soldier ☐ Engineer

   ☐ Teacher ☐ Government officer ☐ Private company ☐ Part-time staff

   ☐ Farmer/agriculturist ☐ Other ………………………………

8. What is your mother's highest level of education?

 Below Bachelor Degree Bachelor Degree or equivalent Master Degree

 PhD/Doctoral Illiterate

9. What is your carer's current occupation?

 Scientist Nurse Doctor Police/Soldier Engineer

 Teacher Government officer Private company Part-time staff

 Farmer/agriculturist Other ………………………………

10. What is your carer's highest level of education?

 Below Bachelor Degree Bachelor Degree or equivalent Master Degree

 PhD/Doctoral Illiterate

11. What is your parents/carers religion?

 Buddhist Christian Roman Catholic Hindu Sikh

 No religion Prefer not to state Other ………………………………………..

Interest and involvement in science

12. Outside of school, which of these places have you visited?

 Public Library Natural Park Local Museum University

 Art Galleries Sport and Recreation Centre National Park Botanical Garden

 Museums or Science and Discovery Centre Local Culture Centre Zoo

 Aquarium Temple/ Abbey Book Store Other …………………………

13. Outside of school, which of the places you visited did you enjoy most? (please select **<u>only one</u>** answer)

 Public Library Natural Park Local Museum University

 Art Galleries Sport and Recreation Centre National Park Botanical Garden

 Museums or Science and Discovery Centre Local Culture Centre Zoo

 Internet Café Aquarium Temple/ Abbey Book Store Other ……………………

14. Why did you like this place most? Please tell me.

Attitude towards science and technology

15. This section explores your perspectives on science and technology. Please tell us how much you agree or disagree with each statement.

No.	Statement	Strongly Agree	Agree	Disagree	Strongly Disagree
15.1	Science and technology make our lives healthier, easier and more comfortable.				
15.2	The application of science and technologies will make people's work more interesting.				
15.3	We should follow up the advance of science and technology's news. Although, we will not be scientist.				
15.4	Science and technology make our way of life change too fast.				
15.5	Science and technology are relevant to everyday life.				
15.6	People obtain great benefits from science and technology more than harmful effects.				
15.7	Science and technology is important to our country's development.				
15.8	Science and technology can sometimes damage people's moral sense.				
15.9	Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.				
15.10	Science and technology research should be supported by government because it brings on obvious immediate benefits.				

Science knowledge background

16. This section will explore your science knowledge background in general. Please answer the questions and don't worry if you don't know all of the answers.

No.	Question	Yes	No	Don't know
16.1	Conductors have a high resistance.			
16.2	Early humans lived at the same time as dinosaurs.			
16.3	The Earth's core is very hot.			
16.4	Your ears are important when it comes to staying balanced.			
16.5	Photosynthesis is the name of the process used by animals to convert sunlight into food.			
16.6	The kinds of fossils found in rocks of different ages differ			

	because life on Earth has changed through time.			
16.7	The three states of matter are solid, liquid, and gas.			
16.8	Insects can see everything things as same as the way we do.			
16.9	The Sun is the earth's primary source of energy.			
16.10	A geologist is a person who studies plants and animals			
16.11	Sound travels faster through water than air.			
16.12	Water freezes at 0 °C (32 °F).			
16.13	Solar power generates electricity from the Sun.			

Science Caravan – Red Route

17. Have your heard about the Science Caravan Project before today?

 Yes, I have **No**, I haven't

18. If you heard about this project, where have you heard this project? (Please select up to **<u>three</u>** answers)

 School/ Teacher Local radio station Newspaper Magazine/ Journal

 National Science Museum, Thailand's website TV Leaflet

 Other …………………………………………………………….

19. What do you hope to get from Science Caravan – Red Route today? (Please select up to three answers)

 Having fun

 I will use knowledge from this caravan for learning science in the classroom.

 I will meet new friends from other schools.

 I will learn how to debate my ideas and give my opinions to other people.

 I hope these activities will inspire me to learn more science and technology.

 Other …………………………………………………………….

After you complete your participation in the science activity, a volunteer or your teacher will give you another questionnaire to complete.

Thank you very much for your participation

A.5: The post questionnaire

University of the West of England
BRISTOL

Participant No. : ………….………
Date: .... **Time:** ……………..
Location/town: ……………………..
Region: ……………………….………..
(For staff)

Post Questionnaire

Developing a Regional Framework for Science Communication Activities in Thailand

I am Wilasinee Triyarat. I am a PhD student in Science Communication, at University of the West of England, Bristol (UK). I want to know about your interest and learning about science. I will use your answers for my studies and your answer will not be connected back to you. If you do not want me to use your information you can ask your teacher to contact me, and I will withdraw your information. Please tell then before the 30th September 2014. The questions will take about and please complete post questionnaire after you finish all activities in Science Caravan – Red Route.

Nickname: ……………………………… **Date of Birth:** …………………………………………
School: …………………….………… **Grade:** …………………..……………….…….…....……...

Attitude towards science and technology

1. This section explores your perspectives on science and technology. Please tell us how much you agree or disagree with each statement.

No.	Statement	Strongly Agree	Agree	Disagree	Strong Disagree
1.1	Science and technology make our lives healthier, easier and more comfortable.				
1.2	The application of science and technologies will make people's work more interesting.				
1.3	We should follow up the advance of science and technology's news. Although, we will not be scientist.				
1.4	Science and technology make our way of life change too fast.				
1.5	Science and technology are relevant to everyday life.				
1.6	People obtain great benefits from science and technology more than harmful effects.				
1.7	Science and technology is important to our country's development.				
1.8	Science and technology can sometimes damage people's moral sense.				

1.9	Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.				
1.10	Science and technology research should be supported by government because it brings on obvious immediate benefits.				

Science knowledge background

12. This section will explore your science knowledge background in general. Please answer the questions and don't worry if you don't know all the answers.

No.	Question	Yes	No	Don't know
2.1	Conductors have a high resistance.			
2.2	Early humans lived at the same time as dinosaurs.			
2.3	The Earth's core is very hot.			
2.4	Your ears are important when it comes to staying balanced.			
2.5	Photosynthesis is the name of the process used by animals to convert sunlight into food.			
2.6	The kinds of fossils found in rocks of different ages differ because life on Earth has changed through time.			
2.7	The three states of matter are solid, liquid, and gas.			
2.8	Insects can see everything things as same as the way we do.			
2.9	The Sun is the earth's primary source of energy.			
2.10	A geologist is a person who studies plants and animals			
2.11	Sound travels faster through water than air.			
2.12	Water freezes at 0 °C (32 °F).			
2.13	Solar power generates electricity from the Sun.			

Experiences in Science Caravan

13. Which order did you carry out the activities in? Right 1-4 next to each activity with 1 being the activity you did first and 4 being the activity you completed last.

Science Show (Start)

……. Science exhibition (1) the exhibition of life science

……. Science exhibition (2) the exhibition of material science

……. Science games

…..... Science demonstration

14. Which was your favourite science activity for today?

 Science Exhibition (1) Science Exhibition (2) Science Experiment

 Science Show Science games

15. Please tell me why?

16. Which was your least favourite science activity for today?

 Science Exhibition (1) Science Exhibition (2) Science Experiment Science Show

17. Please tell me why?

Learning outcome and perception of learning science with science activity

18. This section explores the outcomes of the Science Caravan's activities. Please tell us how much you agree or disagree. There are no right and wrong answers to these statements.

No.	Statement	Strongly Agree	Agree	Disagree	Strongly Disagree
8.1	I found out something I didn't know about science and technology from the science activities in Science Caravan.				
8.2	I don't want to be involved with science activities.				
8.3	I talked with friends about how to solve the problem				
8.4	I didn't read the instructions for activities from a panel or a manual.				
8.5	It was okay for me to express my opinion.				
8.6	I found that using scientific methods to find out the answer was difficult for me.				
8.7	I learnt that science cannot provide perfect answers to problems.				

8.8	The science activities made me enjoy science more.				
8.9	I think I will use some knowledge that I obtained from science activities to improve my study in science class.				
8.10	I will tell my family and my friends about the importance of science and technology from my caravan visit.				

19. Is there anything you would like to add? Please tell us.

Thank you very much for your participation

A.6: The semi-structured interview: student

University of the West of England
BRISTOL

Participant Number: …………
Nickname:………………………
Date of birth: ……………………
Date: ………………………………
Time: ………………………………..

Interview Structure for student

Developing a Regional Framework for Science Communication Activities in Thailand

Good morning/ afternoon. My name is Wilasinee Triyarat. I am PhD Student from the University of the West of England, Bristol (UK). Thank you very much for your agree to participate in this interview. I would like to ask you some questions about your experience in Science Caravan Red Route. I would appreciate it if you could be as honest as possible about what you think. Your answer will only be used for **academic purposes**, and I will **use pseudonyms** during any reporting of the findings. You will ask your teacher to contact me if you do not want to involve this research and you are free to withdraw without having to explain your reasons before 30 November 2015.

1. What have you enjoyed about the science caravan today?

2. What haven't you liked?

3. Did you learn anything new? What was it?

4. What would you like to find out more about?

5. Where else could you find out about science?

6. Are there things you do outside of school to find out more about science? What are they?

7. Is there anything else you would like to add?

I appreciate the time you took for this interview. Thank you very much for your participation.

A.7: The semi-structured interview: Teacher

University of the West of England
BRISTOL

Participant Number: …………
Nickname:………………………
Date of birth: ……………………
Date: ………………………………
Time: ………………………………..

Interview Structure for teacher

Developing a Regional Framework for Science Communication Activities in Thailand

Good morning/ afternoon. My name is Wilasinee Triyarat. I am PhD Student from the University of the West of England, Bristol (UK). Thank you very much for your agree to participate in this interview. I would like to ask you some questions about your student and science learning outside classroom. This interview should take about 20-25 minutes. I would appreciate it if you could be as honest as possible about what you think. Your information will only be used for **academic purposes**, and I will **use pseudonyms** during any reporting of the findings in order to **ensure the confidentiality** of your data. You are free to withdraw without having to explain your reasons before 30 November 2015.

1. Has your school participated in the science caravan before?
2. Why did you decide to participate on this occasion?
3. How is science taught in your school?
4. Apart from at school, what other ways do your students come into contact with science?
5. In your view, what's most useful about the science caravan, for your <u>students?</u>
6. In your view, what's most useful about the science caravan, for you as a <u>teacher?</u>
7. Are there things about the science caravan you would change?
8. How important do you think learning about science is to Thailand?
9. Are there ways traditional Thai beliefs effect students learning around science?
10. What could give students more access to science locally?
11. Is there anything else you would like to add?

I appreciate the time you took for this interview. Thank you very much for your participation.

A.8: The semi-structured interview: NSM

University of the West of England BRISTOL

Participant Number: …………
Nickname:………………………
Date of birth: ……………………
Date: ………………………………
Time: ………………………………..

Interview Structure for NSM's staff

Developing a Regional Framework for Science Communication Activities in Thailand

Good morning/ afternoon. My name is Wilasinee Triyarat. I am PhD Student from the University of the West of England, Bristol (UK). Thank you very much for your agree to participate in this interview. I would like to ask you some questions about your experience in Science Caravan Red Route. This interview should take about 20-25 minutes. I would appreciate it if you could be as honest as possible about what you think. Your information will only be used for **academic purposes**, and I will **use pseudonyms** during any reporting of the findings in order to **ensure the confidentiality** of your data. You are free to withdraw without having to explain your reasons before 30 September 2014.

1. Please tell me about your role in Science Caravan Project.
2. Please tell me about Science Caravan - Red Route Project as the aim and objectives, the kind of project you have been involved in, the project structure, the target audience, locations/setting, science activities etc.
3. In your experience, please tell me, how did you develop each activity to be appropriate with different participants?
4. Please tell me, what sorts of effects might each activity (a specific activity) have on different participants for example over different age, gender, religion, region, local culture characteristics etc.?
5. In your experience, please tell me about the merit points of this caravan.
6. In your experience, please tell me about the limitations of this caravan.
7. For science activities in this caravan, please tell me, which activity is the most popular, why?
8. From your experience, how young participant participate in each science activity in each region (learning behaviour and learning style).
9. In your perception, how Science Caravan has effect on Thai people in each region such as their beliefs, livelihood, attitude toward science, learning science, etc.
10. In your perception, what types of effects do you think projects like the Science Caravan can have on Thai society in science and technology context such as learning science, attitude to science, etc.

11. In your opinion, please tell me how the beliefs, traditional culture, social attitude to science have effect on student and social learning science.
12. Is there anything else you think would be helpful for me to know?

I appreciate the time you took for this interview. Thank you very much for your participation.

Appendix B

Ethical approval

B.1: Ethical approval confirmation

University of the West of England
BRISTOL

Faculty of Health & Applied Sciences
Glenside Campus
Blackberry Hill
Stapleton
Bristol BS16 1DD

Tel: 0117 328 1170

UWE REC REF No: HAS/13/09/115

Date: 10th October 2013

Miss Wilasinee Triyarat
Flat 1
16 Burlington Road
Bristol
BS6 6TL

Dear Wilasinee

Application title: Developing a Regional Framework for Science Communication Activities in Thailand

Your ethics application was considered by the Faculty Research Ethics Committee and, based on the information provided, has been given ethical approval to proceed with the following conditions:

1. Questionnaires/Interview Schedule/Observation sheets: Examples or Final Draft Copies have not been submitted. Please can the applicant submit them to the Committee for approval?

2. **April 2013** has been indicated for start date **-** is this application seeking retrospective permission to proceed? The following seems to indicate that it has: "On audio/video: the research will be conducted between April 2013 and March 2016. The participants will be informed at the beginning of recording that they can withdraw their comment before 30 September 2015, and then the researcher will withdraw their comment from this research. The audio/video will be permanently deleted and removed from the research".
3. **Q7. Please describe how you will store data collected in the course of your research and maintain data protection.** Please clarify whether encryption is used for flash and hard drives (screen passwords alone do not protect data)
4. **Information sheets**: This needs to include the contact details of the supervisory team as well as their names; access to others to raise concerns, etc. should be available to potential participants, whatever their role or country.
5. **UWE Logo:** Please ensure that this is on all documentation associated with this study and check spelling e.g. on the Teacher's consent form, keep is there instead of kept.

If these conditions include providing further information please do not proceed with your research until you have full approval from the committee. You must notify the committee in advance if you wish to make any significant amendments to the original application using the amendment form at
http://www1.uwe.ac.uk/hls/research/researchethicsandgovernance.aspx.

Please note that any information sheets and consent forms should have the UWE logo. Further guidance is available on the web:
http://www1.uwe.ac.uk/aboutus/departmentsandservices/professionalservices/marketingandcommunications/resources.aspx

The following standards conditions also apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee.

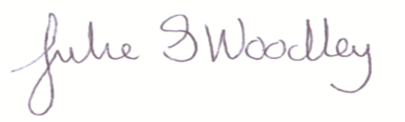
2. You must notify the University Research Ethics Committee if you terminate your research before completion;

3. You must notify the University Research Ethics Committee if there are any serious events or developments in the research that have an ethical dimension.

Please note: The UREC is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the UREC and its committees.

We wish you well with your research.

Yours sincerely



Dr Julie Woodley
Chair
Faculty Research Ethics Committee

c.c Claire Wilkinson

<u>The supporting information as committees' condition for ethical approval</u>

From: Wilasinee2.Triyarat [mailto:Wilasinee2.Triyarat@live.uwe.ac.uk]
Sent: 05 November 2013 15:05
To: Leigh Taylor
Cc: Clare Wilkinson; Emma Weitkamp
Subject: RE: Application for Ethical Review of Research Involving Human Participant: Wilasinee Triyarat 11009688

Dear Leigh,

I would like to explain you how I have addressed the five conditions from the Faculty Research Ethic Committee.

First of all comment, **Questionnaire/Interview Schedule/ Observation sheets: Example or Final Draft Copies have not been submitted.** I have now attached the final draft of interview schedule, observation sheets and questionnaire for two target groups (13-15 years old and 16+ years old) for the committees' consideration. However, the questionnaires for another two groups (7-9 years old and 10-12 years old) will be sent after the pilot work in November because I want to observe these participants about their interest, ability in answers, and how to obtain the data from them effectively after observing them and the pilot questionnaires have been tried out on older age groups. My supervisors are in agreement that as the questionnaire is more difficult to design with a younger age group it makes sense to do this after my pilot work on older age groups.

The second condition, **April 2013 has been indicated for start date – is this application seeking retrospective permission to proceed? The following seems to indicate that it has: "On audio/video: the research will be conducted between April 2013 and March 2016. The participants will be informed at the beginning of recording that they can withdraw their comment before 30 September 2015, and then the researcher will withdraw their comment from this research. The audio/video will be permanently deleted and removed from research".** For this comment, April 2013 to March 2016 included the start date of my PhD – no data has currently been collected. I will start collect the data from 12 to 23 November 2013 in Thailand.

The third condition, **in Q7. Please describe how you will store data collected in the course of your research and maintain data protection. Please clarify whether encryption is used for flash and hard drives screen passwords alone do not protect data).** In the security of data storing, all computer file will be stored on the departmental server or the personal computer. In this research, a UWE computer will be the main computer for data storing. Therefore, the UWE computers are protected by the security encryption technology as Window 7 Bitlocker software. This software can help user to prevent unauthorized users stealing or deleting data. Moreover, all files will be saved in the UWE central file stores (network drive such as H:/ and S:/drive) with password protection. These drives are backed up by UWE IT services. For the personal computer, the Window 7 Bitlocked will be installed for data protection on hard disk, and screensaver password will be used to ensure contents are protected if the computer is left unattended. Moreover, the Window 7 Bitlocker also used to prevent all computer file on a flash-drive or external hard disk by password-protected system. In the audio/video data, they will be transferred to computer after recorded. The original files will be deleted from the recording machine. The files will be stored on a password-protection system. For the paper data, it will be kept in the lockable filling cabinet in personal office. Any data on individuals will be stored separately to ensure confidentiality.

The fourth comment, Information sheets: this need to include the contact details of the supervisory team as well as names; access to others to raise concerns, etc. should be

available to potential participants, whatever their role or country. In this comment, I added the names of my supervisors and their postal address and email on all information sheet. I have not re-attached these but please let me know if you need to see them.

The final comment**,** **UWE logo: please ensure that this on all documentation associated with this study and check spelling e.g. on the Teacher's consent form, keep is their instead of kept**. For this comment, I put the UWE logo on all documentation associated with this research, and my supervisor checked all spelling and grammar for all documents. I have not re-attached these but please let me know if you need to see them.

Please consider and thank you very much for your kindness.

Best regards,

Wilasinee Triyarat (AOM)

Science Communication Unit
Faculty of Health and Life Science
Frenchay Campus, Coldharbour Lane, Bristol
The University of the West of England (UK)
BS16 1QY
Email: Wilasinee2.triyarat@live.uwe.ac.uk
Wilasinee.triyarat@uwe.ac.uk

The Committees' Approval

Email 1

From: Leigh Taylor <Leigh.Taylor@uwe.ac.uk>
Date: 07/11/2013 13:57 (GMT+00:00)
To: Wilasinee Triyarat <Wilasinee2.Triyarat@live.uwe.ac.uk>
Cc: Clare Wilkinson <Clare.Wilkinson@uwe.ac.uk>,Emma Weitkamp <Emma.Weitkamp@uwe.ac.uk>
Subject: RE: Application for Ethical Review of Research Involving Human Participant: Wilasinee Triyarat 11009688

Hi Wilasinee

The Committee have responded to your comments they are happy with your response and now give full approval but they have made one point you are asking for respondent nick names and the names of schools and they cannot see why this is needed as there is a space to record the respondent number.

Kind regards

Leigh

Leigh Taylor (Mrs)
Research Administration (Team Leader)
HAS (Post Award Support)
Research, Business & Innovation
Room 3E35, Frenchay Campus
University of the West of England, Bristol
BS16 1QY

Leigh.Taylor@uwe.ac.uk
Tel: 0117 328 1170
http://rbi.uwe.ac.uk/resadmin.asp

Email 2

Leigh Taylor <Leigh.Taylor@uwe.ac.uk>
Mon 11/11/2013 11:57
Inbox
To: Wilasinee Triyarat <Wilasinee2.Triyarat@live.uwe.ac.uk>;
Cc: Clare Wilkinson <Clare.Wilkinson@uwe.ac.uk>;
Emma Weitkamp <Emma.Weitkamp@uwe.ac.uk>;
You replied on 11/11/2013 13:08.

Hi Wilasinee

The Committee have responded and confirmed that you can use the nick names and school for withdrawal purposes but the final report should not contain any identifying material. They also say it may be easier to just have a list of names and participant numbers held securely away from the questionnaires but if you find it easier to stick to the nick names and school then this is acceptable.

Kind regards

Leigh

Leigh Taylor (Mrs)
Research Administration (Team Leader)
HAS (Post Award Support)
Research, Business & Innovation
Room 3E35, Frenchay Campus
University of the West of England, Bristol
BS16 1QY

Leigh.Taylor@uwe.ac.uk
Tel: 0117 328 1170
http://rbi.uwe.ac.uk/resadmin.asp

B.2: The Amended ethical approval

University of the West of England
BRISTOL

Amendment to Existing Research Ethics Approval

Please complete this form if you wish to make an alteration or amendment to a study that has already been scrutinised and approved by the Faculty Research Ethics Committee and forward it electronically to the Officer of FREC (Leigh.Taylor@uwe.ac.uk)

UWE research ethics reference number:	*HAS/13/09/115*
Title of project:	*Developing a Regional Framework for Science Communication Activities in Thailand*
Date of original approval:	*10th October 2013*
Researcher:	*Miss Wilasinee Triyarat*
Supervisor (if applicable)	*Dr Clare Wilkinson and Dr Emma Weitkamp*

1. Proposed amendment: Please outline the proposed amendment to the existing approved proposal.

This research aims to investigate science communication activities that are occurring at a regional level in Thailand and to explore whether a framework would be a useful structure for regional science communication based activities. There are three objectives as follows:

1) To explore the characteristics of Thai people and geography of Thailand and its effect on science knowledge of Thai people in different regions.

2) To investigate motivation, learning behaviours and learning outcomes of Thai people who attend science communication activities in the four main regions of Thailand (the North, the South, the North-East of Thailand, and the Centre of Thailand).

3) To consider the development of a framework for targeted science communication activities in individual regions in the context of the National Science Museum (NSM), Thailand's Science Caravan project**.**

In this research, a mixed method approach is being used to explore the existing science activities of NSM, Thailand for supporting the needs of Thai people in different regions and a period of data collection in 2014 has already occurred using the methods below:

<u>Data collection</u>

1. Quantitative methods

There are three planned methods for collection of quantitative data as follows:

1) Checklist and tracking visitor observation

The checklist and tracking of visitors' observations will be designed to focus on the learning behaviours categories based on the Visitor Engagement Framework (VEF).

2) The questionnaire

The questionnaire will aim to investigate Thai participants in five areas as follows;

(1) Science knowledge background

(2) Attitudes toward science

(3) Learning outcome

(4) The perception of learning science with the existing activities

(5) The social background/the demography of target audiences

2. Qualitative methods

1) The semi structured interview

This interview is designed for exploring how the visitors engage with these activities from the perspective of NSM, Thailand's staff.

2) The Checklist and tracking visitor observation

This observation will also have an element of qualitative capture to deepen exploration of the existing science activities.

The initial period of data collection garnered the majority of data but highlighted that it would be helpful to carry out a small number of additional interviews with Thai participants and their teachers in summer 2015.

2. Reason for amendment. Please state the reason for the proposed amendment.

Using the existing methods a good deal of data has been collected, but in the questionnaire many participants left open questions empty, or due to their confidence in writing left questions incomplete. The additional interviews would cover identical issues as the original questionnaire but allow for more in-depth elaboration on the part of participants, as well as the support of the researcher being present. In addition it is proposed that a small number of interviews with their teachers are carried out in order to gather information from them on young people's background and its relationship with science learning, skills, behaviours, and attitude toward science, as well as the impact of science activities in the Science Caravan project within the school environment.

3. Ethical issues. Please outline any ethical issues that arise from the amendment that have not already addressed in the original ethical approval. Please also state how these will be addressed.

The additional ethical issues this amendment raises are highlighted below:

Research method:

1. **The qualitative method**
   1) **Participants (New)**

The interviews with young people in an informal environment will encourage them to present their opinions and experiences with the science and caravan activities in more depth than can be gained through the questionnaires. The questions posed will be identical in nature to those within the questionnaire, with some re-written in a more open format.

2) **Teachers (New)**

This interview will be designed to explore perceptions of children's learning styles and learning behaviours from the teacher's perspective, including how the Science Caravan has affected their students interest in science. Moreover, the interview will be used to explore the opportunities of young Thai people to participate in informal science learning opportunities (such as the Science Caravan – Red Route) including access to science and technology information and informal learning opportunities in each region. Furthermore, this research activity will explore the teacher's perception of the importance of science to pupils' likely careers.

2. The participants of research

1) Participants

The sample group is identical to that used in the original questionnaire: visitors, 10-15 years old.

2) Teachers (New)

Teachers who participate with their pupils in the Science Caravan – Red Route will bes ampled. Informants will be drawn from each region. They will be the teachers who have responsibility for providing young students access to science activities. These teachers will be science teachers or have science teaching experiences.

3. The sampling sample

1) Young participants

The same sampling approach will be used as that for the original questionnaire, though the sample size will be smaller.

2) Teachers (New)

10 teachers who are responsible for encouraging children to participate in science activities in the Science Caravan in each region will be invited for interview.

<u>The arrangement for obtaining informed consent:</u>

- The procedure will be identical as that planned previously, the researcher will provide the information sheet and the consent form for the Director of schools (equivalent of Head Teacher) who will visit the Science Caravan in order to agree consent for the students that are younger than 18 years old.
- (New) Information sheets and consent forms will also be provided for young local participants and teachers and have been updated to reflect the nature of the interview. They will sign this form before starting the interview and these are attached with this form.

<u>The arrangement for participants to withdraw from the study:</u>

The withdrawal procedure is the same as the original ethics application.

<u>The research generates personal data:</u>

The personal data plans are the same as the original ethics application.

<u>Data protection:</u>

The plans for data protection are the same as the original ethics application. The updated University statement on data protection has been added to the consent forms.

<u>The risks to participants:</u>

(New additions) The semi-structured interview questions will be designed to be clear and easy to understand. Interviewees will be reminded that they are being recorded via Dictaphone and can ask to stop at anytime.

<u>The other potential risks to researchers:</u>

In this study, there are no potential risk to researcher and participants that are greater than those in daily life. The risk assessment form already covers interaction during interviews.

To be completed by supervisor/ Lead researcher:

Signature:	*Clare Wilkinson (electronically)*
Date:	*01/04/15*

To be completed by Research Ethics Chair:

Send out for review:	*Yes* *x No*
Comments:	*Well thought out amendment were revised documentation covers any additional ethical issues*
Outcome:	*xApprove* *Approve subject to conditions* *Refer to Research Ethics Committee*
Date approved:	*13th April 2015*
Signature:	*Dr Julie Woodley (via e-mail)*

Guidance on notifying UREC/FREC of an amendment.

Your study was approved based on the information provided at the time of application. If the study design changes significantly, for example a new population is to be recruited, a different method of recruitment is planned, new or different methods of data collection are planned then you need to inform the REC and explain what the ethical implications might be. Significant changes in participant information sheets, consent forms should be notified to the REC for review with an explanation of the need for changes. Any other significant changes to the protocol with ethical implications should be submitted as substantial amendments to the original application. If you are unsure about whether or not notification of an amendment is necessary please consult your departmental ethics lead or Chair of FREC.

B.3: The information sheet

B.3.1: The Information Sheet: Teachers for students

University of the West of England
BRISTOL

My name is Wilasinee Triyarat. I am PhD student in Science Communication at the University of the West of England, Bristol (UWE). My PhD research title is **"Developing a Regional Framework for Science Communication Activities in Thailand".** The aim of this research is to investigate science communication activities that are occurring at a regional level in Thailand, and to explore whether a framework would be a useful structure for regional science communication based activities. This research was funded from the Royal Thai Government, and the National Science Museum, Thailand is supporting the research. .

Your students are being invited to take part in a research study because your students are in the age group we are looking at, and they are living in one of four regions; The Northern, the Northeast, the Southern and the Centre of Thailand. Before you decide it is important for you to understand why research is being done and what it will involve. Please take time to read the following information carefully, and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw by the 30th November 2015 and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not effect on your students and your school. Thank you for reading this.

Procedure of the research: if you agree to take part, your students will be interviewed after they participate with science activities in the Science Caravan, and I will be recording by audio recorder. The interview will take around 10 minutes. During the students involvement with this research they will not be alone with me. Moreover, the students will be asked to fill out the questionnaires about their learning outcome from participating with science activities. The questionnaire will take around 10 minutes. During the students involvement with this research they will not be alone with me.

Risks and benefits: There are no risks or discomforts associated with this research. Your students might find the question and topic interesting; your students will be helping to improve the structure for regional science communication based activities.

Confidential: All records are kept confidential and will be available only to the researcher and supervisory team. The interview will ask for the date of birth and the first letter of student's name to create a code number for data storage, and will not include your student's name. It will not be possible to identify your student's answer. The interview will be recorded with note-taking, and audio recording. The data will be stored securely (in a lockable filing cabinet and/or on password-protected computer drive). No data will be disclosed to any other persons, with the exception of academic publication for example in conference papers, articles and books. Within the thesis itself and any subsequent publications pseudonyms will be used to ensure the confidentiality of data.

This study is under supervisory team of Dr Clare Wilkinson (Associate Professor in Science Communication) and Dr Emma Weitkamp (Associate Professor in Science Communication) from UWE, and ethical approval has been granted to this project by UWE.

Thank you for your participation in this research. If you have any further questions, please do not hesitate to contact Wilasinee Triyarat via email wilasinee2.triyarat@live.uwe.ac.uk.

Researcher:

Wilasinee Triyarat

PhD student in Science Communication

The supervisory team:

Dr. Clare Wilkinson

Associate Professor in Science Communication

Dr. Emma Weitcamp

Associate Professor in Science Communication

Science Communication Unit, Faculty of Health and Applied Science

The University of the West of England, Bristol

Coldharbour Lane, Bristol, BS16 1OY

B.3.2: The Information Sheet: Teachers for teacher interview

University of the West of England
BRISTOL

Information Sheet for Teacher Interviews

My name is Wilasinee Triyarat. I am a PhD student in Science Communication at the University of the West of England, Bristol (UWE). My PhD research title is **"Developing a Regional Framework for Science Communication Activities in Thailand"**. The aim of this research is to investigate science communication activities that are occurring at a regional level in Thailand, and to explore whether a framework would be a useful structure for regional science communication activities. This research was funded from the Royal Thai Government, and the National Science Museum, Thailand is supporting it. .

You are being invited to take part in this research study because you are a key person associated to the Science Caravan project. Before you decide if you want to participate it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully, and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw until 30th November 2015 and without giving a reason. A decision to withdraw, or a decision not to take part, will not effect on your future career. Thank you for reading this.

Procedure of the research: if you agree to take part, you will be interviewed and asked about science learning and the science caravan, including your student learning experiences. The researcher will interview you via online communication (SKYPE), email or individual interview, including face to face. The interview will be recorded by audio recording and note taking. The data from the recorder will be transcribed. The interview will take no longer than 30 minutes.

Risks and benefits: There are no risks or discomforts associated with this research. You might find the question and topic interesting by providing feedback; you will be helping to improve the structure for regional science communication based activities.

Confidential: All records are kept confidential and will be available only to the researcher and supervisor team. The interview will ask for the date of birth and the first letter of your name to create code number for data storage, and will not include your name. It will not be possible to identify your answer. The data will be stored securely (in a lockable filing cabinet and/or on password-protected computer drive). No data will be disclosed to any other persons, with the exception of academic publication for example in conference papers, articles and books. Within the thesis itself and any subsequent publications pseudonyms will be used to ensure the confidentiality of data.

This study is under supervisory team of Dr Clare Wilkinson (Associate Professor in Science Communication) and Dr Emma Weitkamp (Associate Professor in Science Communication) from UWE, and ethical approval has been granted to this project by UWE.

Thank you for your participation in this research. If you have any further questions, please do not hesitate to contact Wilasinee Triyarat via email wilasinee2.triyarat@live.uwe.ac.uk.

Researcher:
Wilasinee Triyarat
PhD student in Science Communication

The supervisory team:
Dr. Clare Wilkinson
Associate Professor in Science Communication
Dr. Emma Weitcamp
Associate Professor in Science Communication
Science Communication Unit, Faculty of Health and Applied Science
The University of the West of England, Bristol
Coldharbour Lane, Bristol, BS16 1OY

B.3.3: The Information Sheet for NSM staff interviews

University of the West of England
BRISTOL

Information Sheet for NSM Staff

My name is Wilasinee Triyarat. I am PhD student in Science Communication at the University of the West of England, Bristol (UWE). My PhD research title is **"Developing a Regional Framework for Science Communication Activities in Thailand"**. The aim of this research is to investigate science communication activities that are occurring at a regional level in Thailand, and to explore whether a framework would be a useful structure for regional science communication based activities. This research was funded from the Royal Thai Government, and the National Science Museum, Thailand is supporting organisation in the facilities and useful information throughout the data collection in Thailand.

You are being invited to take part in this research study because you are a key person working in the Science Caravan project. Before you decide if you want to participate it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully, and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw until 30th September 2015 and without giving a reason. A decision to withdraw, or a decision not to take part, will not effect on your future career. Thank you for reading this.

Procedure of the research: if you agree to take part, you will be interviewed and asked about science activities in the Science Caravan project included the participants of this event. The researcher will interview you via online communication (SKYPE)/email or individual interview at the National Science Museum, Thailand. The interview will be recorded by audio recording. The data from the recorder will be transcribed. The interview will take no longer than 30 minutes.

Risks and benefits: There are no risks or discomforts associated with this research. You might find the question and topic interesting by providing feedback; you will be helping to improve the structure for regional science communication based activities.

Confidential: All records are kept confidential and will be available only to the researcher and supervisor team. The interview will ask for the date of birth and the first letter of your name to create code number for datastorage, and will not include your name. It will not be possible to identify your answer. The data will be stored securely (in a lockable filing cabinet and/or on password-protected computer drive). No data will be disclosed to any other persons, with the exception of academic publication for example in conference papers, articles and books. Within the thesis itself and any subsequent publications pseudonyms will be used to ensure the confidentiality of data.

This study is under supervisory team of Dr Clare Wilkinson (Associate Professor in Science Communication) and Dr Emma Weitkamp (Associate Professor in Science Communication) from UWE, and ethical approval has been granted to this project by UWE.

Thank you for your participation in this research. If you have any further questions, please do not hesitate to contact Wilasinee Triyarat via email wilasinee2.triyarat@live.uwe.ac.uk.

Researcher:
Wilasinee Triyarat
PhD student in Science Communication

The supervisory team:
Dr. Clare Wilkinson
Associate Professor in Science Communication
Dr. Emma Weitcamp
Associate Professor in Science Communication
Science Communication Unit, Faculty of Health and Applied Science
The University of the West of England, Bristol
Coldharbour Lane, Bristol, BS16 1OY

B.3.4: The Information Sheet for students

Information Sheet for Student

Developing a Regional Framework for Science Communication Activities in Thailand

My name is Wilasinee Triyarat. I am PhD student in Science Communication at the University of the West of England, Bristol (UWE). My PhD research title is “Developing a Regional Framework for Science Communication Activities in Thailand”.

The questionnaire is part of my PhD thesis, which is funded by the Royal Thai Government.

The research I wish to conduct for my PhD will look at how you interact with science activities in Science Caravan, and what the outcomes are for you.

If you agree to take part, you will fill out the questionnaires and this will take around 10 minutes. Please feel free to ask me or one of the other staff members questions.

If you decide after that you would prefer not to participate in this project please ask the teacher you have come with to contact me via email wilasinee2.triyarat@live.uwe.ac.uk before the 30th September 2015.

I will keep your questionnaire locked away, and only I can see it, I will write a report, and I will only use your answer without your name.

Thank you

Wilasinee Triyarat
PhD student in Science Communication
Email: wilasinee2.triyarat@live.uwe.ac.uk

The supervisory team:

Dr. Clare Wilkinson
Associate Professor in Science Communication
Dr. Emma Weitcamp
Associate Professor in Science Communication
Science Communication Unit, Faculty of Health and Applied Science
The University of the West of England, Bristol
Coldharbour Lane, Bristol, BS16 1OY

B.3.5: The consent form: Teachers for students

University of the West of England
BRISTOL

The Consent Form for Teacher

Developing a Regional Framework for Science Communication Activities in Thailand

Thank you for your participation. The personal information collected in this interview will be processed by the University in accordance with the terms and conditions of the 1998 Data Protection Act. We will hold your data securely and not make it available to any third party unless permitted or required to do so by law. Your personal information will be used/processed as follows. Please tick the box that you agree with the following statement:

1. I have read and understand the information sheet.	
2. I have been given the opportunity to ask questions about the research and they were answered to my satisfaction.	
3. I agree to allow my students to participate in the research project being conducted by Wilasinee Triyarat during April 2013 to March 2016.	
4. I understand that some audio/video recording in the interview will be studied and excerpts may be illustrated in the PhD thesis and in future papers, journal articles and books that may be written by researcher.	
5. I understand that the data gathered will be stored securely. The final thesis will be ketp in the UWE archive.	

Teacher's signature box:

Teacher's signature: ……………………………………………. Date: …………………….…….……

Please PRINT name: …………………………………………………………...………………………….

School/Organization:……………………………………………………………………………………

Researcher's signature: ………………….………………... Date: …………………………

Thank you

Wilasinee Triyarat

PhD student in Science Communication

Email: wilasinee2.triyarat@live.uwe.ac.uk

The supervisory team:

Dr. Clare Wilkinson

Associate Professor in Science Communication

Dr. Emma Weitcamp

Associate Professor in Science Communication

Science Communication Unit, Faculty of Health and Applied Science

The University of the West of England, Bristol

Coldharbour Lane, Bristol, BS16 1OY

B.3.6: The consent form: Teachers

Participant's code-number: ……………..

The Interview Consent Form for teacher

Developing a Regional Framework for Science Communication Activities in Thailand

Thank you for taking the time to complete this interview. The personal information collected in this interview will be processed by the University in accordance with the terms and conditions of the 1998 Data Protection Act. We will hold your data securely and not make it available to any third party unless permitted or required to do so by law. Your personal information will be used/processed as follows. Please tick the box that you agree with the following statement:

1. I have read and understanding the information sheet.	
2. I have been given the opportunity to ask questions about the research and they were answered to my satisfaction.	
3. I agree to participate in the research project being conducted by Wilasinee Triyarat during April 2013 to March 2016	
4. I understand that transcripts of verbal communication and/or email communication with the researcher will be studied and excerpts may be quoted in the PhD thesis and in future papers, journal articles and books that may be written by researcher.	
5. I understand that the data gathered will be stored securely and audio recording will be destroyed after transcribed information. The final thesis will be kept in the UWE archive.	

Participant's signature box:

Participant's signature: …………………………………………………… **Date:** …………………………

Please PRINT name: ……………………………………………………………

Researcher's signature: …………………………………… **Date:** ………………………………

Thank you

Wilasinee Triyarat

PhD student in Science Communication

Email: wilasinee2.triyarat@live.uwe.ac.uk

The supervisory team:

Dr. Clare Wilkinson

Associate Professor in Science Communication

Dr. Emma Weitcamp

Associate Professor in Science Communication

Science Communication Unit, Faculty of Health and Applied Science

The University of the West of England, Bristol

Coldharbour Lane, Bristol, BS16 1OY

B.3.7: The consent form: Students

UWE BRISTOL University of the West of England

Participant's code-number: ……………..

The Interview Consent Form for Student

Developing a Regional Framework for Science Communication Activities in Thailand

Thank you for taking the time to complete this interview. Please tick the face that you agree with the following statement:

1. I have read and understand the information sheet.	☺ ☹
2. I have been given the opportunity to ask questions about the research and they were answered.	☺ ☹
3. I agree to participate in the research project being conducted by Wilasinee Triyarat during April 2013 to March 2016.	☺ ☹
4. I understand that notes from my interview will be studied and they may appear (without my name) in future papers, journal articles and books that may be written by the researcher.	☺ ☹
5. I understand that the data gathered will be stored securely by the researcher and the audio recording will be destroyed after it is written down.	☺ ☹

The personal information collected in this interview will be processed by the University in accordance with the terms and conditions of the 1998 Data Protection Act. We will hold your data securely and not make it available to any third party unless permitted or required to do so by law.

Participant's signature box:

Participant's signature: …………………………………………………… **Date:** …………………………

Please PRINT name: …………………………………………………………

Researcher's signature: …………………………………… **Date:**

………………………………

Thank you

Wilasinee Triyarat

PhD student in Science Communication

Email: wilasinee2.triyarat@live.uwe.ac.uk

The supervisory team:

Dr. Clare Wilkinson

Associate Professor in Science Communication

Dr. Emma Weitcamp
Associate Professor in Science Communication
Science Communication Unit, Faculty of Health and Applied Science
The University of the West of England, Bristol
Coldharbour Lane, Bristol, BS16 1OY

Appendix C

Additional Information Quantitative Results

C.1: Attitudes towards science and technology of all participants

Attitudes toward science and technology		N	Z	*P-value*	Note
1. Science and technology make our lives healthier, easier and more comfortable.	Negative Ranks	301[a]	-3.737[b]	0.000	a. Post_Attitude_1 < Pre_Atitude_1
	Positive Ranks	397[b]			b. Post_Attitude_1 > Pre_Atitude_1
	Ties	702[c]			c. Post_Attitude_1 = Pre_Atitude_1
	Total	1400			
2. The application of science and technologies will make people's work more interesting.	Negative Ranks	333[d]	-.235[b]	0.814	d. Post_Attitude_2 < Pre_Attitude_2
	Positive Ranks	326[e]			e. Post_Attitude_2 > Pre_Attitude_2
	Ties	741[f]			f. Post_Attitude_2 = Pre_Attitude_2
	Total	1400			
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	Negative Ranks	318[g]	-2.191[b]	0.028	g. Post_Attitude_3 < Pre_Attitude_3
	Positive Ranks	403[h]			h. Post_Attitude_3 > Pre_Attitude_3
	Ties	679[i]			i. Post_Attitude_3 = Pre_Attitude_3
	Total	1400			
4. Science and technology make our way of life change too fast.	Negative Ranks	538[j]	-8.801[c]	0.000	j. Post_Attitude_4 < Pre_Attitude_4
	Positive Ranks	305[k]			k. Post_Attitude_4 > Pre_Attitude_4
	Ties	557[l]			l. Post_Attitude_4 = Pre_Attitude_4
	Total	1400			
5. Science and technology are relevant to everyday life.	Negative Ranks	368[m]	-1.541[b]	0.123	m. Post_Attitude_5 < Pre_Attitude_5
	Positive Ranks	389[n]			n. Post_Attitude_5 > Pre_Attitude_5
	Ties	643[o]			o. Post_Attitude_5 = Pre_Attitude_5
	Total	1400			
6. People obtain great benefits from science and technology more than harmful effects.	Negative Ranks	299[p]	-6.175[b]	0.000	p. Post_Attitude_6 < Pre_Attitude_6
	Positive Ranks	466[q]			q. Post_Attitude_6 > Pre_Attitude_6
	Ties	635[r]			r. Post_Attitude_6 = Pre_Attitude_6
	Total	1400			
7. Science and technology is important to our country's development.	Negative Ranks	322[s]	-3.480[b]	0.001	s. Post_Attitude_7 < Pre_Attitude_7
	Positive Ranks	414[t]			t. Post_Attitude_7 > Pre_Attitude_7
	Ties	664[u]			u. Post_Attitude_7 = Pre_Attitude_7
	Total	1400			
8. Science and technology can sometimes damage people's moral sense.	Negative Ranks	562[v]	-8.321[c]	0.000	v. Post_Attitude_8 < Pre_Attitude_8
	Positive Ranks	300[w]			w. Post_Attitude_8 > Pre_Attitude_8
	Ties	538[x]			x. Post_Attitude_8 = Pre_Attitude_8
	Total	1400			
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	Negative Ranks	311[y]	-8.985[b]	0.000	y. Post_Attitude_9 < Pre_Attitude_9
	Positive Ranks	536[z]			z. Post_Attitude_9 > Pre_Attitude_9
	Ties	553[aa]			aa. Post_Attitude_9 = Pre_Attitude_9
	Total	1400			
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	Negative Ranks	343[ab]	-2.454[b]	0.014	ab. Post_Attitude_10 < Pre_Attitude_10
	Positive Ranks	424[ac]			ac. Post_Attitude_10 > Pre_Attitude_10
	Ties	633[ad]			ad. Post_Attitude_10 = Pre_Attitude_10
	Total	1400			

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

C.2: Changing Attitudes towards science and technology of all participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group –Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	11.9% (N=167)	88.1% (N=1,233)	76.2% (N=1,066)	12.9% (N=180)	87.1% (N=1,220)	74.2% (N=1,040)	-2.0% (N=-26)
2. The application of science and technologies will make people's work more interesting.	11.4% (N=160)	88.6% (N=1,240)	77.2% (N=1,080)	11.2% (N=157)	88.8% (N=1,243)	77.6% (N=1,086)	0.4% (N=6)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	11.0% (N=154)	89.0% (N=1,246)	78.0% (N=1,092)	17.3% (N=242)	82.7% (N=1,158)	65.4% (N=916)	-12.6% (N=-176)
4. Science and technology make our way of life change too fast.	37.1% (N=519)	62.9% (N=881)	25.8% (N=362)	25.8% (N=361)	74.2% (N=1,039)	48.4% (N=678)	22.6% (N=316)
5. Science and technology are relevant to everyday life.	15.6% (N=219)	84.4% (N=1,181)	68.8% (N=962)	15.4% (N=216)	84.6% (N=1,184)	69.2% (N=968)	0.4% (N=6)
6. People obtain great benefits from science and technology more than harmful effects.	16.1% (N=226)	83.9% (N=1,174)	67.8% (N=948)	14.4% (N=201)	85.6% (N=1,199)	71.2% (N=998)	3.4% (N=50)
7. Science and technology is important to our country's development.	16.6% (N=232)	83.4% (N=1,168)	66.8% (N=936)	16.4% (N=229)	83.6% (N=1,171)	67.2% (N=942)	0.4% (N=6)
8. Science and technology can sometimes damage people's moral sense.	27.1% (N=380)	72.9% (N=1,020)	45.8% (N=640)	20.3% (N=284)	79.7% (N=1,116)	59.4% (N=832)	13.6% (N=192)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	32.3% (N=452)	67.7% (N=948)	35.4% (N=496)	24.4% (N=341)	75.6% (N=1,059)	51.2% (N=718)	15.8% (N=222)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	13.6% (N=191)	86.4% (N=1,209)	72.8% (N=1,018)	16.6% (N=233)	83.4% (N=1,167)	66.8% (N=934)	-6.0% (N=-84)

C.3: Changing Attitudes towards science and technology of the northeast participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group – Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	5.7% (N=20)	94.3% (N=330)	88.6% (N=310)	10.6% (N=37)	89.4% (N=313)	78.8% (N=276)	-9.8% (N=-34)
2. The application of science and technologies will make people's work more interesting.	4.3% (N=15)	95.7% (N=335)	91.4% (N=320)	6.9% (N=24)	93.1% (N=326)	86.2% (N=302)	-5.2% (N=-18)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	12.6% (N=44)	87.4% (N=306)	74.8% (N=262)	14.3% (N=50)	85.7% (N=300)	71.4% (N=250)	-3.4% (N=-12)
4. Science and technology make our way of life change too fast.	24.9% (N=87)	75.1% (N=263)	50.2% (N=176)	25.7% (N=90)	74.3% (N=260)	48.6% (N=170)	-1.6% (N=-6)
5. Science and technology are relevant to everyday life.	11.1% (N=39)	88.9% (N=311)	77.8% (N=272)	10.6% (N=37)	89.4% (N=313)	78.8% (N=276)	1.0% (N=4)
6. People obtain great benefits from science and technology more than harmful effects.	21.1% (N=74)	78.9% (N=276)	57.8% (N=202)	14.3% (N=50)	85.7% (N=300)	71.4% (N=250)	13.6% (N=48)
7. Science and technology is important to our country's development.	13.7% (N=48)	86.3% (N=302)	72.6% (N=254)	12.9% (N=45)	87.1% (N=305)	74.2% (N=260)	1.6% (N=6)
8. Science and technology can sometimes damage people's moral sense.	16.3% (N=57)	83.7% (N=293)	67.4% (N=236)	11.1% (N=39)	88.9% (N=311)	77.7% (N=272)	10.4% (N=36)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	16.9% (N=59)	83.1% (N=291)	66.2% (N=232)	16.6% (N=58)	83.4% (N=292)	66.8% (N=234)	0.6% (N=2)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	10.9% (N=38)	89.1% (N=312)	78.2% (N=274)	8.6% (N=30)	91.4% (N=320)	82.9% (N=290)	4.6% (N=16)

C.4: Changing Attitudes towards science and technology of the northern participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group – Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	12.6% (N=44)	87.4% (N=306)	74.8% (N=262)	12.6% (N=44)	87.4% (N=306)	74.8% (N=262)	0.0% (N=0)
2. The application of science and technologies will make people's work more interesting.	15.1% (N=53)	84.9% (N=297)	69.8% (N=244)	14.0% (N=49)	86.0% (N=301)	72.0% (N=252)	2.2% (N=8)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	10.3% (N=36)	89.7% (N=314)	79.4% (N=278)	30.9% (N=108)	69.1% (N=242)	38.2% (N=134)	-41.1% (N=-144)
4. Science and technology make our way of life change too fast.	47.4% (N=166)	52.6% (N=184)	5.1% (N=18)	15.1% (N=53)	84.9% (N=297)	69.7% (N=244)	64.6% (N=226)
5. Science and technology are relevant to everyday life.	20.9% (N=73)	79.1% (N=277)	58.2% (N=204)	22.3% (N=78)	77.7% (N=272)	55.4% (N=194)	-2.8% (N=-10)
6. People obtain great benefits from science and technology more than harmful effects.	15.4% (N=54)	84.6% (N=296)	69.2% (N=242)	17.1% (N=60)	82.9% (N=290)	65.8% (N=230)	-3.4% (N=-12)
7. Science and technology is important to our country's development.	16.6% (N=58)	83.4% (N=292)	66.8% (N=234)	18.6% (N=65)	81.4% (N=285)	62.8% (N=220)	-4.0% (N=-14)
8. Science and technology can sometimes damage people's moral sense.	30.3% (N=106)	69.7% (N=244)	39.4% (N=138)	11.7% (N=41)	88.3% (N=309)	76.6% (N=268)	37.2% (N=130)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	36.9% (N=129)	63.1% (N=221)	26.2% (N=92)	12.0% (N=42)	88.0% (N=308)	76.0% (N=266)	49.8% (N=174)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	14.3% (N=50)	85.7% (N=300)	71.4% (N=250)	26.6% (N=93)	73.4% (N=257)	46.8% (N=164)	-24.6% (N=-86)

C.5: Changing Attitudes towards science and technology of the central participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group – Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	17.1% (N=60)	82.9% (N=290)	65.8% (N=230)	8.6% (N=30)	91.4% (N=320)	82.9% (N=290)	17.0% (N=60)
2. The application of science and technologies will make people's work more interesting.	14.9% (N=52)	85.1% (N=298)	70.2% (N=246)	10.9% (N=38)	89.1% (N=312)	78.2% (N=274)	8.0% (N=28)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	10.9% (N=38)	89.1% (N=312)	78.2% (N=274)	14.6% (N=51)	85.4% (N=299)	70.8% (N=248)	-7.4% (N=-26)
4. Science and technology make our way of life change too fast.	38.0% (N=133)	62.0% (N=217)	24.0% (N=84)	24.9% (N=87)	75.1% (N=263)	50.2% (N=176)	26.2% (N=92)
5. Science and technology are relevant to everyday life.	20.0% (N=70)	80.0% (N=280)	60.0% (N=210)	16.6% (N=58)	83.4% (N=292)	66.8% (N=234)	6.8% (N=24)
6. People obtain great benefits from science and technology more than harmful effects.	16.3% (N=57)	83.7% (N=293)	67.4% (N=236)	16.9% (N=59)	83.1% (N=291)	66.2% (N=232)	-1.2% (N=-4)
7. Science and technology is important to our country's development.	18.0% (N=63)	82.0% (N=287)	64.0% (N=224)	15.7% (N=55)	84.3% (N=295)	68.6% (N=240)	4.6% (N=16)
8. Science and technology can sometimes damage people's moral sense.	32.9% (N=115)	67.1% (N=235)	34.2% (N=120)	28.0% (N=98)	72.0% (N=252)	44.0% (N=154)	9.8% (N=34)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	33.1% (N=116)	66.9% (N=234)	33.8% (N=118)	33.7% (N=118)	66.3% (N=232)	32.6% (N=114)	-1.2% (N=-4)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	16.0% (N=56)	84.0% (N=294)	68.0% (N=238)	16.9% (N=59)	83.1% (N=291)	66.2% (N=232)	-1.8% (N=-6)

C.6: Changing Attitudes towards science and technology of the southern participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group – Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	12.3% (N=43)	87.7% (N=307)	75.4% (N=264)	19.7% (N=69)	80.3% (N=281)	60.6% (N=212)	-14.8% (N=-52)
2. The application of science and technologies will make people's work more interesting.	11.4% (N=40)	88.6% (N=310)	77.2% (N=270)	13.1% (N=46)	86.9% (N=304)	73.8% (N=258)	-3.4% (N=-12)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	10.3% (N=36)	89.7% (N=314)	79.4% (N=278)	9.4% (N=33)	90.6% (N=317)	81.2% (N=284)	1.8% (N=6)
4. Science and technology make our way of life change too fast.	38.0% (N=133)	62.0% (N=217)	24.0% (N=84)	37.4% (N=131)	62.6% (N=219)	25.2% (N=88)	1.2% (N=4)
5. Science and technology are relevant to everyday life.	10.6% (N=37)	89.4% (N=313)	78.8% (N=276)	12.3% (N=43)	87.7% (N=307)	75.4% (N=264)	-3.4% (N=-1)
6. People obtain great benefits from science and technology more than harmful effects.	11.7% (N=41)	88.3% (N=309)	76.6% (N=268)	9.1% (N=32)	90.9% (N=318)	81.8% (N=286)	5.2% (N=18)
7. Science and technology is important to our country's development.	18.0% (N=63)	82.0% (N=287)	64.0% (N=224)	18.3% (N=64)	81.7% (N=286)	63.4% (N=222)	-0.6% (N=-2)
8. Science and technology can sometimes damage people's moral sense.	29.1% (N=102)	70.9% (N=248)	41.8% (N=146)	30.3% (N=106)	69.7% (N=244)	39.4% (N=138)	-2.4% (N=-8)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	42.3% (N=148)	57.7% (N=202)	15.4% (N=54)	35.1% (N=123)	64.9% (N=227)	29.8% (N=104)	14.4% (N=50)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	13.4% (N=47)	86.6% (N=303)	73.2% (N=256)	14.6% (N=51)	85.4% (N=299)	70.8% (N=248)	-2.4% (N=-8)

C.7: Changing Attitudes towards science and technology of participants age between 10-12 years old

	The pre attitudes			**The post attitudes**			**Changing attitude (the post-test – the pre-test)**
	Disagree group	**Agree group**	**The pre-test of attitude (Agree group – Disagree group**	**Disagree group**	**Agree group**	**The post-test of attitude (Agree group –Disagree group**	
1. Science and technology make our lives healthier, easier and more comfortable.	13.2% (N=122)	86.8% (N=800)	73.6% (N=678)	30.7% (N=283)	69.3% (N=639)	38.6% (N=356)	-35.0% (N=-322)
2. The application of science and technologies will make people's work more interesting.	13.4% (N=124)	86.6% (N=798)	73.2% (N=674)	29.4% (N=271)	70.6% (N=651)	41.2% (N=380)	-32.0% (N=-294)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	13.2% (N=122)	86.8% (N=800)	73.6% (N=678)	28.3% (N=261)	71.7% (N=661)	43.4% (N=400)	-30.2% (N=-278)
4. Science and technology make our way of life change too fast.	39.5% (N=364)	60.5% (N=558)	21.0% (N=194)	25.4% (N=234)	74.6% (N=688)	49.2% (N=454)	28.2% (N=260)
5. Science and technology are relevant to everyday life.	19.1% (N=176)	80.9% (N=746)	61.8% (N=570)	29.2% (N=269)	70.8% (N=653)	41.6% (N=384)	-20.2% (N=-186)
6. People obtain great benefits from science and technology more than harmful effects.	18.3% (N=169)	81.7% (N=753)	63.4% (N=584)	29.7% (N=274)	70.3% (N=648)	40.6% (N=374)	-22.8% (N=-210)
7. Science and technology is important to our country's development.	16.4% (N=151)	83.6% (N=771)	67.2% (N=620)	32.8% (N=302)	67.2% (N=620)	34.4% (N=318)	-32.8% (N=-302)
8. Science and technology can sometimes damage people's moral sense.	28.7% (N=265)	71.3% (N=657)	42.6% (N=392)	21.1% (N=195)	78.9% (N=727)	57.8% (N=532)	15.2% (N=140)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	32.0% (N=295)	68.0% (N=627)	36.0% (N=332)	44.8% (N=413)	55.2% (N=509)	10.4% (N=96)	-25.6% (N=-236)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	15.7% (N=145)	84.3% (N=777)	68.6% (N=632)	28.9% (N=266)	71.1% (N=656)	42.2% (N=390)	-26.4% (N=-242)

C.8: Changing Attitudes towards science and technology of participants age between 13-15 years old

	The pre attitudes			**The post attitudes**			**Changing attitude (the post-test – the pre-test)**
	Disagree group	**Agree group**	**The pre-test of attitude (Agree group – Disagree group**	**Disagree group**	**Agree group**	**The post-test of attitude (Agree group –Disagree group**	
1. Science and technology make our lives healthier, easier and more comfortable.	9.4% (N=45)	90.6% (N=433)	81.2% (N=388)	33.3% (N=159)	66.7% (N=319)	33.4% (N=160)	-47.8% (N=-228)
2. The application of science and technologies will make people's work more interesting.	7.5% (N=36)	92.5% (N=442)	85.0% (N=406)	28.9% (N=138)	71.1% (N=340)	42.2% (N=202)	-42.8% (N=-204)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	6.7% (N=32)	93.3% (N=446)	86.6% (N=414)	24.1% (N=115)	75.9% (N=363)	51.8% (N=248)	-34.8% (N=-166)
4. Science and technology make our way of life change too fast.	32.4% (N=155)	67.6% (N=323)	35.2% (N=168)	26.6% (N=127)	73.4% (N=351)	46.8% (N=224)	11.6% (N=56)
5. Science and technology are relevant to everyday life.	9.0% (N=43)	91.0% (N=435)	82.0% (N=392)	29.5% (N=141)	70.5% (N=337)	41.0% (N=196)	-41.0% (N=-196)
6. People obtain great benefits from science and technology more than harmful effects.	11.9% (N=57)	88.1% (N=421)	76.2% (N=364)	32.8% (N=157)	67.2% (N=321)	34.4% (N=164)	-41.8% (N=-200)
7. Science and technology is important to our country's development.	16.9% (N=81)	83.1% (N=397)	66.2% (N=316)	30.8% (N=147)	69.2% (N=331)	38.4% (N=184)	-27.8% (N=-132)
8. Science and technology can sometimes damage people's moral sense.	24.1% (N=115)	75.9% (N=363)	51.8% (N=248)	18.6% (N=89)	81.4% (N=389)	62.8% (N=300)	11.0% (N=52)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	32.8% (N=157)	67.2% (N=321)	34.4% (N=164)	40.6% (N=194)	59.4% (N=284)	18.8% (N=90)	-15.6% (N=-74)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	9.6% (N=46)	90.4% (N=432)	80.8% (N=386)	27.4% (N=131)	72.6% (N=347)	45.2% (N=216)	-35.6% (N=-170)

C.9: Changing Attitudes towards science and technology of male participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group –Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	11.2% (N=78)	88.8% (N=619)	77.6% (N=541)	12.3% (N=86)	87.7% (N=611)	75.4% (N=525)	-2.2% (N=-16)
2. The application of science and technologies will make people's work more interesting.	13.6% (N=95)	86.4% (N=602)	72.8% (N=507)	11.9% (N=83)	88.1% (N=614)	76.2% (N=531)	3.4% (N=24)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	11.9% (N=83)	88.1% (N=614)	76.2% (N=531)	19.2% (N=134)	80.8% (N=563)	61.6% (N=429)	-14.6% (N=-102)
4. Science and technology make our way of life change too fast.	36.4% (N=254)	63.6% (N=443)	27.2% (N=189)	26.1% (N=182)	73.9% (N=515)	47.8% (N=333)	20.6% (N=144)
5. Science and technology are relevant to everyday life.	16.5% (N=115)	83.5% (N=582)	67.0% (N=467)	17.4% (N=121)	82.6% (N=576)	65.2% (N=455)	-1.8% (N=-12)
6. People obtain great benefits from science and technology more than harmful effects.	19.5% (N=136)	80.5% (N=561)	61.0% (N=425)	14.9% (N=104)	85.1% (N=593)	70.2% (N=489)	9.2% (N=64)
7. Science and technology is important to our country's development.	18.7% (N=130)	81.3% (N=567)	62.6% (N=437)	16.1% (N=112)	83.9% (N=585)	67.8% (N=473)	5.2% (N=36)
8. Science and technology can sometimes damage people's moral sense.	27.0% (N=188)	73.0% (N=509)	46.0% (N=321)	22.8% (N=159)	77.2% (N=538)	54.4% (N=379)	8.4% (N=58)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	31.6% (N=220)	68.4% (N=477)	36.8% (N=257)	24.1% (N=168)	75.9% (N=529)	51.8% (N=361)	15.0% (N=104)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	15.6% (N=109)	84.4% (N=588)	68.8% (N=479)	17.9% (N=125)	82.1% (N=572)	64.2% (N=447)	-4.6% (N=-32)

C.10: Changing Attitudes towards science and technology of female participants

	The pre attitudes			The post attitudes			Changing attitude (the post-test – the pre-test)
	Disagree group	Agree group	The pre-test of attitude (Agree group – Disagree group	Disagree group	Agree group	The post-test of attitude (Agree group –Disagree group	
1. Science and technology make our lives healthier, easier and more comfortable.	12.7% (N=89)	87.3% (N=614)	74.6% (N=525)	13.4% (N=94)	86.6% (N=609)	73.2% (N=515)	-1.4% (N=-10)
2. The application of science and technologies will make people's work more interesting.	9.2% (N=65)	90.8% (N=638)	81.6% (N=573)	10.5% (N=74)	89.5% (N=629)	79.0% (N=555)	-2.6% (N=-18)
3. We should follow up the advance of science and technology's news. Although, we will not be scientist.	10.1% (N=71)	89.9% (N=632)	79.8% (N=561)	15.4% (N=108)	84.6% (N=595)	69.2% (N=487)	-10.6% (N=-74)
4. Science and technology make our way of life change too fast.	37.7% (N=265)	62.3% (N=438)	24.6% (N=173)	25.5% (N=179)	74.5% (N=524)	49.0% (N=345)	24.4% (N=172)
5. Science and technology are relevant to everyday life.	14.8% (N=104)	85.2% (N=599)	70.4% (N=495)	13.5% (N=95)	86.5% (N=608)	73.0% (N=513)	2.6% (N=18)
6. People obtain great benefits from science and technology more than harmful effects.	12.8% (N=90)	87.2% (N=613)	74.4% (N=523)	13.8% (N=97)	86.2% (N=606)	72.4% (N=509)	-2.0% (N=-14)
7. Science and technology is important to our country's development.	14.5% (N=102)	85.5% (N=601)	71.0% (N=499)	16.6% (N=117)	83.4% (N=586)	66.8% (N=469)	-4.2% (N=-30)
8. Science and technology can sometimes damage people's moral sense.	27.3% (N=192)	72.7% (N=511)	45.4% (N=319)	17.8% (N=125)	82.2% (N=578)	64.4% (N=453)	19.0% (N=134)
9. Thai people trust superstition too much. Therefore, we should use science and technology to solve this problem.	33.0% (N=232)	67.0% (N=471)	34.0% (N=239)	24.6% (N=173)	75.4% (N=530)	50.8% (N=357)	16.8% (N=118)
10. Science and technology research should be supported by government because it brings on obvious immediate benefits.	11.7% (N=82)	88.3% (N=621)	76.6% (N=539)	15.4% (N=108)	84.6% (N=595)	69.2% (N=487)	-7.4% (N=-52)

C.11: Learning outcome from participating in the Science Caravan of all participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	46.3% (N=648)	46.8% (N=656)	5.1% (N=71)	1.8% (N=25)	93.1% (N=1,304)	6.9% (N=96)	86.2% (N=1,208)
2. I don't want to be involved with science activities.	22.0% (N=308)	23.2% (N=325)	24.4% (N=342)	30.4% (N=425)	45.2% (N=633)	54.8% (N=767)	-9.6% (N=-134)
3. I talked with friends about how to solve the problem.	40.9% (N=572)	42.4% (N=594)	12.3% (N=172)	4.4% (N=62)	83.3% (N=1,166)	16.7% (N=234)	66.6% (N=932)
4. I didn't read the instructions for activities from a panel or a manual.	19.1% (N=268)	26.4% (N=369)	33.9% (N=475)	20.6% (N=288)	45.5% (N=637)	54.5% (N=763)	-9.0% (N=-126)
5. It was okay for me to express my opinion.	37.0% (N=518)	45.2% (N=633)	13.6% (N=190)	4.2% (N=59)	82.2% (N=1,151)	17.8% (N=249)	64.4% (N=902)
6. I found that using scientific methods to find out the answer was difficult for me.	35.7% (N=500)	39.1% (N=548)	18.1% (N=253)	7.1% (N=99)	74.9% (N=1,048)	25.1% (N=352)	49.8% (N=696)
7. I learnt that science cannot provide perfect answers to problems.	26.4% (N=370)	28.7% (N=401)	30.8% (N=431)	14.1% (N=198)	55.1% (N=771)	44.9% (N=629)	10.2% (N=142)
8. The science activities made me enjoy science more.	60.5% (N=847)	30.9% (N=432)	6.0% (N=85)	2.6% (N=36)	91.4% (N=1,279)	8.6% (N=121)	82.8% (N=1,158)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	52.5% (N=735)	37.6% (N=526)	7.6% (N=107)	2.3% (N=32)	90.1% (N=1,261)	9.9% (N=139)	80.2% (N=1,122)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	51.1% (N=716)	38.6% (N=541)	6.9% (N=96)	3.4% (N=47)	89.7% (N=1,257)	10.3% (N=143)	79.4% (N=1,114)

C.12: Learning outcome from participating in the Science Caravan of the northeast participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	56.3% (N=197)	36.3% (N=127)	5.1% (N=18)	2.3% (N=8)	92.6% (N=324)	7.4% (N=26)	85.2% (N=298)
2. I don't want to be involved with science activities.	30.3% (N=106)	17.4% (N=61)	20.3% (N=71)	32.0% (N=112)	47.7% (N=167)	52.3% (N=183)	-4.6% (N=-16)
3. I talked with friends about how to solve the problem.	48.3% (N=169)	34.3% (N=120)	10.6% (N=37)	6.8% (N=24)	82.6% (N=289)	17.4% (N=61)	65.2% (N=228)
4. I didn't read the instructions for activities from a panel or a manual.	27.4% (N=96)	30.0% (N=105)	25.7% (N=90)	16.9% (N=59)	57.4% (N=201)	42.6% (N=149)	14.8% (N=52)
5. It was okay for me to express my opinion.	49.7% (N=174)	34.6% (N=121)	12.3% (N=43)	3.4% (N=12)	84.3% (N=295)	15.7% (N=55)	68.6% (N=240)
6. I found that using scientific methods to find out the answer was difficult for me.	42.6% (N=149)	35.7% (N=125)	12.3% (N=43)	9.4% (N=33)	78.3% (N=274)	21.7% (N=76)	56.6% (N=198)
7. I learnt that science cannot provide perfect answers to problems.	38.0% (N=133)	32.3% (N=113)	20.6% (N=72)	9.1% (N=32)	70.3% (N=246)	29.7% (N=104)	40.6% (N=142)
8. The science activities made me enjoy science more.	59.4% (N=208)	27.4% (N=96)	10.3% (N=36)	2.8% (N=10)	86.9% (N=304)	13.1% (N=46)	73.8% (N=258)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	58.0% (N=203)	30.6% (N=107)	8.0% (N=28)	3.4% (N=12)	88.6% (N=310)	11.4% (N=40)	77.1% (N=270)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	56.3% (N=197)	34.0% (N=119)	6.0% (N=21)	3.7% (N=13)	90.3% (N=316)	9.7% (N=34)	80.6% (N=282)

C.13: Learning outcome from participating in the Science Caravan of the northern participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	36.3% (N=127)	55.4% (N=194)	7.1% (N=25)	1.2% (N=4)	91.7% (N=321)	8.3% (N=29)	83.4% (N=292)
2. I don't want to be involved with science activities.	32.9% (N=115)	22.0% (N=77)	18.9% (N=66)	26.3% (N=92)	54.9% (N=192)	45.2% (N=158)	9.7% (N=34)
3. I talked with friends about how to solve the problem.	36.9% (N=129)	45.4% (N=159)	12.9% (N=45)	4.8% (N=17)	82.3% (N=288)	17.7% (N=62)	64.6% (N=226)
4. I didn't read the instructions for activities from a panel or a manual.	21.7% (N=76)	33.7% (N=118)	23.2% (N=81)	21.4% (N=75)	55.4% (N=194)	44.6% (N=156)	10.8% (N=38)
5. It was okay for me to express my opinion.	34.0% (N=119)	48.0% (N=168)	12.9% (N=45)	5.1% (N=18)	82.0% (N=287)	18.0% (N=63)	64.0% (N=224)
6. I found that using scientific methods to find out the answer was difficult for me.	34.3% (N=120)	41.1% (N=144)	17.2% (N=60)	7.4% (N=26)	75.4% (N=264)	24.6% (N=86)	50.8% (N=178)
7. I learnt that science cannot provide perfect answers to problems.	23.4% (N=82)	25.2% (N=88)	36.6% (N=128)	14.8% (N=52)	48.6% (N=170)	51.4% (N=180)	-2.8% (N=-10)
8. The science activities made me enjoy science more.	50.3% (N=176)	37.1% (N=130)	9.1% (N=32)	3.5% (N=12)	87.4% (N=306)	12.6% (N=44)	74.8% (N=262)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	48.5% (N=170)	42.9% (N=150)	6.6% (N=23)	2.0% (N=7)	91.4% (N=320)	8.6% (N=30)	82.8% (N=290)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	46.3% (N=162)	40.9% (N=143)	9.1% (N=32)	3.7% (N=13)	87.2% (N=305)	12.8% (N=45)	74.4% (N=260)

C.14: Learning outcome from participating in the Science Caravan of the Central participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	51.1% (N=179)	42.9% (N=150)	2.6% (N=9)	3.4% (N=12)	94.0% (N=329)	6.0% (N=21)	88.0% (N=308)
2. I don't want to be involved with science activities.	14.6% (N=51)	29.4% (N=103)	27.4% (N=96)	28.6% (N=100)	44.0% (N=154)	56.0% (N=196)	-12.0% (N=-42)
3. I talked with friends about how to solve the problem.	43.4% (N=152)	39.7% (N=139)	12.6% (N=44)	4.3% (N=15)	83.1% (N=291)	16.9% (N=59)	66.2% (N=232)
4. I didn't read the instructions for activities from a panel or a manual.	14.6% (N=51)	23.7% (N=83)	37.4% (N=131)	24.3% (N=85)	38.3% (N=134)	61.7% (N=216)	-23.4% (N=-82)
5. It was okay for me to express my opinion.	36.3% (N=127)	43.1% (N=151)	14.9% (N=52)	5.7% (N=20)	79.4% (N=278)	20.6% (N=72)	58.8% (N=206)
6. I found that using scientific methods to find out the answer was difficult for me.	34.6% (N=121)	41.1% (N=144)	17.4% (N=61)	6.9% (N=24)	75.7% (N=265)	24.3% (N=85)	51.4% (N=180)
7. I learnt that science cannot provide perfect answers to problems.	24.5% (N=86)	28.9% (N=101)	26.6% (N=93)	20.0% (N=70)	53.4% (N=187)	46.6% (N=163)	6.8% (N=24)
8. The science activities made me enjoy science more.	70.3% (N=246)	23.4% (N=82)	2.3% (N=8)	4.0% (N=14)	93.7% (N=328)	6.3% (N=22)	87.4% (N=306)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	57.7% (N=202)	31.4% (N=110)	8.6% (N=30)	2.3% (N=8)	89.1% (N=312)	10.9% (N=38)	78.2% (N=274)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	54.0% (N=189)	34.9% (N=122)	7.4% (N=26)	3.7% (N=13)	88.9% (N=311)	11.1% (N=39)	77.8% (N=272)

C.15: Learning outcome from participating in the Science Caravan of the southern participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	41.4% (N=145)	52.9% (N=185)	5.4% (N=19)	0.3% (N=1)	94.3% (N=330)	5.7% (N=20)	88.6% (N=310)
2. I don't want to be involved with science activities.	16.9% (N=59)	27.1% (N=95)	28.0% (N=98)	28.0% (N=98)	44.0% (N=154)	56.0% (N=196)	-12.0% (N=-42)
3. I talked with friends about how to solve the problem.	34.9% (N=122)	50.3% (N=176)	13.1% (N=46)	1.7% (N=6)	85.2% (N=298)	14.8% (N=52)	70.4% (N=246)
4. I didn't read the instructions for activities from a panel or a manual.	13.1% (N=46)	28.6% (N=100)	38.9% (N=136)	19.4% (N=68)	41.7% (N=146)	58.3% (N=204)	-16.6% (N=-58)
5. It was okay for me to express my opinion.	28.0% (N=98)	55.1% (N=193)	14.3% (N=50)	2.6% (N=9)	83.1% (N=291)	16.9% (N=59)	66.2% (N=232)
6. I found that using scientific methods to find out the answer was difficult for me.	31.4% (N=110)	38.6% (N=135)	25.4% (N=89)	4.6% (N=16)	70.0% (N=245)	30.0% (N=105)	40.0% (N=140)
7. I learnt that science cannot provide perfect answers to problems.	19.7% (N=69)	28.3% (N=99)	39.4% (N=138)	12.6% (N=44)	48.0% (N=168)	52.0% (N=182)	-4.0% (N=-14)
8. The science activities made me enjoy science more.	62.0% (N=217)	35.4% (N=124)	2.6% (N=9)	0.0% (N=0)	97.4% (N=341)	2.6% (N=9)	94.8% (N=332)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	45.7% (N=160)	45.4% (N=159)	7.4% (N=26)	1.5% (N=5)	91.1% (N=319)	8.9% (N=31)	82.2% (N=288)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	48.0% (N=168)	44.9% (N=157)	4.9% (N=17)	2.2% (N=8)	92.9% (N=325)	7.1% (N=25)	85.8% (N=300)

C.16: Learning outcome from participating in the Science Caravan of the participants age 10-12 years old

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	45.8% (N=422)	46.1% (N=425)	6.0% (N=55)	2.1% (N=20)	91.9% (N=847)	8.1% (N=75)	83.8% (N=772)
2. I don't want to be involved with science activities.	23.5% (N=217)	23.2% (N=214)	25.6% (N=236)	27.7% (N=255)	46.7% (N=431)	53.3% (N=491)	-6.6% (N=-60)
3. I talked with friends about how to solve the problem.	39.5% (N=364)	40.8% (N=376)	13.9% (N=128)	5.8% (N=54)	80.3% (N=740)	19.7% (N=182)	60.6% (N=558)
4. I didn't read the instructions for activities from a panel or a manual.	21.1% (N=195)	26.5% (N=244)	32.8% (N=302)	19.6% (N=181)	47.6% (N=439)	52.4% (N=483)	-4.8% (N=-44)
5. It was okay for me to express my opinion.	37.0% (N=341)	42.3% (N=390)	15.7% (N=145)	5.0% (N=46)	79.3% (N=731)	20.7% (N=191)	58.6% (N=540)
6. I found that using scientific methods to find out the answer was difficult for me.	36.0% (N=332)	40.3% (N=372)	16.2% (N=149)	7.5% (N=69)	76.3% (N=704)	23.7% (N=218)	52.6% (N=486)
7. I learnt that science cannot provide perfect answers to problems.	28.1% (N=259)	29.7% (N=274)	28.9% (N=266)	13.3% (N=123)	57.8% (N=533)	42.2% (N=389)	15.6% (N=144)
8. The science activities made me enjoy science more.	59.4% (N=548)	30.4% (N=280)	7.2% (N=66)	3.0% (N=28)	89.8% (N=828)	10.2% (N=94)	79.6% (N=734)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	51.0% (N=470)	36.3% (N=335)	9.3% (N=86)	3.4% (N=31)	87.3% (N=805)	12.7% (N=117)	74.6% (N=688)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	50.3% (N=464)	37.3% (N=344)	7.9% (N=73)	4.5% (N=41)	87.6% (N=808)	12.4% (N=114)	75.2% (N=694)

C.17: Learning outcome from participating in the Science Caravan of the participants age 13-15 years old

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	47.3% (N=226)	48.3% (N=231)	3.3% (N=16)	1.1% (N=5)	95.6% (N=457)	4.4% (N=21)	91.2% (N=436)
2. I don't want to be involved with science activities.	19.0% (N=91)	23.2% (N=111)	22.2% (N=106)	35.6% (N=170)	42.2% (N=202)	57.8% (N=276)	-15.5% (N=-74)
3. I talked with friends about how to solve the problem.	43.5% (N=208)	45.6% (N=218)	9.2% (N=44)	1.7% (N=8)	89.1% (N=426)	10.9% (N=52)	78.2% (N=374)
4. I didn't read the instructions for activities from a panel or a manual.	15.3% (N=73)	26.1% (N=125)	36.2% (N=173)	22.4% (N=107)	41.4% (N=198)	58.6% (N=280)	-17.2% (N=-82)
5. It was okay for me to express my opinion.	37.1% (N=177)	50.8% (N=243)	9.4% (N=45)	2.7% (N=13)	87.9% (N=420)	12.1% (N=58)	75.8% (N=362)
6. I found that using scientific methods to find out the answer was difficult for me.	35.1% (N=168)	36.8% (N=176)	21.8% (N=104)	6.3% (N=30)	71.9% (N=344)	28.1% (N=134)	43.8% (N=210)
7. I learnt that science cannot provide perfect answers to problems.	23.2% (N=111)	26.6% (N=127)	34.5% (N=165)	15.7% (N=75)	49.8% (N=238)	50.2% (N=240)	-0.4% (N=-2)
8. The science activities made me enjoy science more.	62.6% (N=299)	31.8% (N=152)	4.0% (N=19)	1.6% (N=8)	94.4% (N=451)	5.6% (N=27)	88.8% (N=424)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	55.4% (N=265)	40.0% (N=191)	4.4% (N=21)	0.2% (N=1)	95.4% (N=456)	4.6% (N=22)	90.8% (N=434)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	52.7% (N=252)	41.2% (N=197)	4.8% (N=23)	1.3% (N=6)	93.9% (N=449)	6.1% (N=29)	87.8% (N=420)

C.18: Learning outcome from participating in the Science Caravan of the male participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	45.4% (N=316)	46.9% (N=327)	5.3% (N=37)	2.4% (N=17)	92.3% (N=643)	7.7% (N=54)	84.6% (N=589)
2. I don't want to be involved with science activities.	23.8% (N=166)	28.4% (N=198)	23.5% (N=164)	24.3% (N=169)	52.2% (N=364)	47.8% (N=333)	4.4% (N=31)
3. I talked with friends about how to solve the problem.	38.7% (N=270)	42.9% (N=299)	13.3% (N=93)	5.1% (N=35)	81.6% (N=569)	18.4% (N=128)	63.2% (N=441)
4. I didn't read the instructions for activities from a panel or a manual.	19.8% (N=138)	32.7% (N=228)	30.0% (N=209)	17.5% (N=122)	52.5% (N=366)	47.5% (N=331)	5.0% (N=35)
5. It was okay for me to express my opinion.	35.9% (N=250)	44.0% (N=307)	14.5% (N=101)	5.6% (N=39)	79.9% (N=557)	20.1% (N=140)	59.8% (N=417)
6. I found that using scientific methods to find out the answer was difficult for me.	35.0% (N=244)	42.3% (N=295)	16.1% (N=112)	6.6% (N=46)	77.3% (N=539)	22.7% (N=158)	54.6% (N=381)
7. I learnt that science cannot provide perfect answers to problems.	30.7% (N=214)	31.6% (N=220)	26.1% (N=182)	11.6% (N=81)	62.3% (N=434)	37.7% (N=263)	24.6% (N=171)
8. The science activities made me enjoy science more.	55.4% (N=386)	33.1% (N=231)	7.9% (N=55)	3.6% (N=25)	88.5% (N=617)	11.5% (N=80)	77.0% (N=537)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	49.4% (N=344)	39.4% (N=275)	8.3% (N=58)	2.9% (N=20)	88.8% (N=619)	11.2% (N=78)	77.6% (N=541)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	49.4% (N=344)	37.1% (N=259)	8.6% (N=60)	4.9% (N=34)	86.5% (N=603)	13.5% (N=94)	73.0% (N=509)

C.19: Learning outcome from participating in the Science Caravan of the female participants

Learning outcome	%Respondents						the different of %Respondents between agree and disagree
	Strong agree	agree	disagree	Strong disagree	Agree (strong agree + agree)	Disagree (strong disagree + disagree)	
1. I found out something I didn't know about science and technology from the science activities in Science Caravan.	47.2% (N=332)	46.8% (N=329)	4.8% (N=34)	1.2% (N=8)	94.0% (N=661)	6.0% (N=42)	88.0% (N=619)
2. I don't want to be involved with science activities.	20.2% (N=142)	18.1% (N=127)	25.3% (N=178)	36.4% (N=256)	38.3% (N=269)	61.7% (N=434)	-23.4% (N=-165)
3. I talked with friends about how to solve the problem.	43.0% (N=302)	42.0% (N=295)	11.2% (N=79)	3.8% (N=27)	85.0% (N=597)	15.0% (N=106)	70.0% (N=491)
4. I didn't read the instructions for activities from a panel or a manual.	18.5% (N=130)	20.1% (N=141)	37.8% (N=266)	23.6% (N=166)	38.6% (N=271)	61.4% (N=432)	-22.9% (N=-161)
5. It was okay for me to express my opinion.	38.1% (N=268)	46.4% (N=326)	12.7% (N=89)	2.8% (N=20)	84.5% (N=594)	15.5% (N=109)	69.0% (N=485)
6. I found that using scientific methods to find out the answer was difficult for me.	36.4% (N=256)	36.0% (N=253)	20.1% (N=141)	7.5% (N=53)	72.4% (N=509)	27.6% (N=194)	44.8% (N=315)
7. I learnt that science cannot provide perfect answers to problems.	22.2% (N=156)	25.7% (N=181)	35.5% (N=249)	16.6% (N=117)	47.9% (N=337)	52.1% (N=366)	-4.2% (N=-29)
8. The science activities made me enjoy science more.	65.6% (N=461)	28.6% (N=201)	4.2% (N=30)	1.6% (N=11)	94.2% (N=662)	5.8% (N=41)	88.4% (N=621)
9. I think I will use some knowledge that I obtained from science activities to improve my study in science class.	55.6% (N=391)	35.7% (N=251)	7.0% (N=49)	1.7% (N=12)	91.3% (N=642)	8.7% (N=61)	82.6% (N=581)
10. I will tell my family and my friends about the importance of science and technology from my caravan visit.	52.9% (N=372)	40.1% (N=282)	5.2% (N=36)	1.8% (N=13)	93.0% (N=654)	7.0% (N=49)	86.0% (N=605)

Appendix D

Additional Information Qualitative Results

D.1: Interviewees' profile – students

Region	No.	Name	Gender	Host or Guest school's student	Level of education (Primary school = 10 -12 years old and High school = 13-15 years old)	Date of interview	Interview method
The Northeast	1	Kingkeaw	Female	Guest school	High school	12-06-2014	In person
	2	Champ	Male	Guest school	High school	12-06-2014	In person
	3	Kade	Female	Guest school	Primary school	12-06-2014	In person
	4	Nooch	Female	Guest school	Primary school	12-06-2014	In person
	5	Pang	Female	Guest school	Primary school	12-06-2014	In person
	6	Mam	Female	Host school	High school	16-06-2014	In person
	7	Ford	Male	Host school	Primary school	16-06-2014	In person
	8	Fame	Male	Host school	Primary school	16-06-2014	In person
	9	Ote	Male	Host school	Primary school	16-06-2014	In person
	10	Nim	Female	Host school	Primary school	16-06-2014	In person
The North	11	Baramee	Female	Guest school	Primary school	29-06-2014	In person
	12	Amitta	Female	Guest school	Primary school	29-06-2014	In person
	13	Dangthong	Female	Guest school	High school	29-06-2014	In person
	14	Prach	Male	Guest school	Primary school	29-06-2014	In person
	15	Sangchan	Female	Guest school	High school	04-07-2014	In person
	16	Soratree	Female	Host school	High school	04-07-2014	In person
	17	Chansuda	Female	Host school	High school	04-07-2014	In person
	18	Penpan	Female	Host school	High school	04-07-2014	In person
	19	Ponprapa	Female	Host school	High school	04-07-2014	In person
	20	Bambam	Female	Host school	Primary school	04-07-2014	In person
The Centre	21	Chompu	Female	Host school	Primary school	17-07-2014	In person
	22	Man	Male	Host school	High school	17-07-2014	In person
	23	Navin	Male	Host school	High school	17-07-2014	In person
	24	Som	Female	Host school	Primary school	17-07-2014	In person
	25	Golf	Male	Host school	Primary school	17-07-2014	In person
	26	Mod	Male	Guest school	Primary school	17-07-2014	In person
	27	Preaw	Female	Guest school	Primary school	22-07-2014	In person
	28	Keng	Male	Guest school	High school	22-07-2014	In person
	29	Dream	Male	Guest school	Primary school	22-07-2014	In person
	30	Beem	Female	Guest school	High school	22-07-2014	In person
The South	31	Pinmuk	Female	Host school	High school	31-07-2014	In person
	32	Chanthapim	Female	Host school	High school	31-07-2014	In person
	33	Adisak	Male	Host school	High school	31-07-2014	In person
	34	Somsak	Male	Host school	Primary school	31-07-2014	In person
	35	Wuttipong	Male	Host school	Primary school	31-07-2014	In person
	36	Fang	Female	Guest school	High school	04-08-2014	In person
	37	Pompam	Female	Guest school	High school	04-08-2014	In person
	38	Burin	Male	Guest school	High school	04-08-2014	In person
	39	Framk	Male	Guest school	High school	04-08-2014	In person
	40	Gang	Male	Guest school	High school	04-08-2014	In person

D.2: Interviewees' profile – teachers

Region	No.		Name	Gender	Host or Guest school's student	Subject	Date of interview	In r
The Northeast	1		Tipprapa	Female	Guest school	Non-science	12-06-2014	In
	2		Manop	Male	Guest school	Science	12-06-2014	In
	3		Jantima	Female	Host school	Science	12-06-2014	In
	4		Bunyapat	Female	Host school	Science	12-06-2014	In
	5		Kittiya	Female	Host school	Science	12-06-2014	In
The North	6		Supawan	Female	Host school	Science	29-06-2014	In
	7		Pongpat	Male	Host school	Non-science	29-06-2014	In
	8		Rawiwan	Female	Guest school	Science	29-06-2014	In
	9		Anupong	Male	Guest school	Science	29-06-2014	In
	10		Ponpan	Female	Host school	Science	04-07-2014	In
The Centre	11		Jitree	Female	Host school	Science	17-07-2014	In
	12		Panya	Male	Host school	Science	17-07-2014	In
	13		Tippawan	Female	Guest school	Science	17-07-2014	In
	14		Saksuriya	Male	Guest school	Non-science	21-07-2014	In
	15		Damrongsak	Male	Host school	Science	21-07-2014	In
The South	16		Amponpan	Female	Host school	Science	31-07-2014	In
	17		Saksit	Male	Host school	Science	31-07-2014	In
	18		Chompunuch	Female	Guest school	Non-science	31-07-2014	In
	19		Janthima	Female	Guest school	Science	31-08-2014	In
	20		Sittisak	Male	Host school	Science	03-08-2014	In

D.3: Interviewees' profile – NSM staff

No.	Name	Gender	Role relate with NSM	Date of interview	Interview method
1	Supranee	Female	Science communicator	18-11-2013	In person
2	Chorkeaw	Female	Science communicator	18-11-2013	In person
3	Rawipa	Female	Science communicator	18-11-2013	In person
4	Prayuk	Male	Science communicator	18-11-2013	In person
5	Mongkol	Male	Science communicator	18-11-2013	In person
6	Kraisak	Male	Science communicator	19-11-2013	In person
7	Wipawan	Female	Science communicator	19-11-2013	In person
8	Manote	Male	Science communicator	19-11-2013	In person
9	Srikanya	Female	Science communicator	19-11-2013	In person
10	Panupat	Male	Director	19-11-2013	In person
11	Raumpon	Female	Science communicator	23-11-2013	In person
12	Sukanya	Female	Director	23-11-2013	In person
13	Ekkaparp	Male	Science communicator	23-11-2013	In person
14	Anusit	Male	Science communicator	23-11-2013	In person
15	Nantiya	Female	Science communicator	23-11-2013	In person
16	Panya	Male	Science communicator	13-06-2014	In person
17	Kreangkrai	Male	Science communicator	17-07-2014	In person
18	Chittima	Female	Science communicator	24-07-2014	In person
19	Ekkawit	Male	Science communicator	26-07-2014	In person
20	Supat	Male	Science communicator	26-07-2014	In person
21	Aranya	Female	Science communicator	01-08-2014	In person
22	Akkradach	Male	Science communicator	01-08-2014	In person

D.4: Coding analysis of the student interviews

Theme	Sub-theme		Coding (sample)	Count (N = response)			
				The Northeast	The North	The Centre	The South
1. Informal science learning experiences of young local people							
	1.1 Informal science learning setting						
	1)	Local administrative organisation	Free Wi-Fi Service, people can use smart phone, notebook to access internet	1	-	1	-
	2)	Home computer	Using a home computer to search about scientific knowledge	4	3	3	6
	3)	Internet cafe	Accessing science information to support science homework.	2	3	1	2
	4)	Rice fields	Learning about ecosystem of rice fields (which involves many insects and animals).	2	-	-	-
	5)	School library	The school library has more dinosaur books than the public library, but still not enough for students.	4	4	4	6
	6)	Public library	• Using books	-	2	-	-
			• Using free Wi-Fi	-	1	-	-
	7)	Local natural history museum	There are a lot of dinosaur models and also demonstrations of dinosaur skeletons (regarding a school trip to Phu Wiang Dinosaur Museum)	5	-	-	-
	8)	Local aquarium	• There are a lot of fish and aquatic animals (regarding a school trip to Maekong Underwater World).	1	-	-	-
			• Visiting the Institute of Marine Science Burapha University (an aquarium visited on a school trip).	1	-	-	-
			• Visiting Phuket Aquarium with family.	-	-	-	1
	9)	National park	Learning about the ecosystem and environment (school trip).	-	1	-	1
	10)	Zoo	Visiting zoo with family in summer. There are a lot of animals.	-	1	1	1
	11)	National Science Museum (NSM)	Visiting NSM with a school trip. There are a lot of science activities and experiments.	-	2	-	2

	12)	Local Science Centre	Visiting a local science centre with family on the weekend. There are a lot science activities and experiments.	-	1	-	1
	13)	Book store	There are a lot of new science books.	-	1	-	-
	14)	Friend's home	Doing science homework together because there are a lot of new science books and a computer with internet in a friend's home.	-	1	1	-
1.2 Informal science learning resources							
	1)	Website search engine	Using Google.	1	3	-	-
	2)	Family	Helping students do science homework.	-	-	2	1
	3)	Science programme and news on TV	There are a lot of interesting natural science documentaries about natural science, technology innovation, health science.	1	2	1	-
1.3 Informal science learning events							
	1)	Science camp	Participating in science camp with other schools at Wa Ko Prachuap Khirikhan Science Park.	-	-	1	-
	2)	Science festival	Participating in science festival at local university with school trip.	-	2	-	-
2. Factors affecting informal science learning experiences of local young participants							
2.1 School			• Main resources of science books and media to support student science learning in free time	6	5	7	6
			• Support for the visiting informal science learning setting.	5	5	-	3
2.2 Teacher			Main people support informal and formal scientific learning for students.	3	2	1	1
2.3 Friends			Sharing scientific knowledge to find the answers for science homework together.	-	1	-	-
2.4 Family			• Support visiting informal learning science setting.	-	2	1	2
			• Support scientific knowledge for doing science homework.	-	-	2	-
3. The Science Caravan and local young participants							
3.1 Learning with science activities in the Science Caravan: Learning behaviours							

1)	Watching and observing	• Watched the explainer demonstrate a science experiment in the science show.	4	3	2	3
		• Observed the explainer do the activities and tried to follow the demonstration.	1	-	-	-
2)	Doing experiments/ activities	• Did experiments independently.	5	7	9	11
3)	Sharing knowledge and asking other people	• Helped students from another school to find an answer.	1	-	-	-
		• Worked with a team to find a science answer in a science game.	2	-	-	-
		• Asked the staff to help with the circuit.	-	2	-	-
4)	Repeating doing experiment/ activities	Repeated the balloon experiment again, which developed understanding of why the big balloon did not form in the plastic bottle the first time.	1	1	1	-
5)	Using experiences to solve the problem	In mathematics game, used geometry learned in classroom to fix the pieces of the tangrams following the required pattern.	1	2	1	-
3.2 Limits of learning with science activities in the Science Caravan						
1)	Activities do not support different groups of participants	• The content of some activities are too difficult for some groups of participants. For example, the Chicken Voice is good for primary school students, but it should be more difficult and challenging for high school students.	3	2	1	1
		• Participant could not thread the string through the paper cup to make the Chicken cup.	-	-	1	-
2)	Limits of labels for hands-on exhibition	• Because of difficult words the information on the labels of the material exhibition were too difficult for young participants; they could not play with the exhibit by only reading the labels.	1	-	-	-

		• The size of letters on labels was too small to comfortably read.	-	-	1	-
3)	Time for activities was too limited	Tangram is too difficult an activity for primary school students; more time needed to play tangram.	1	-	-	-
4)	Too many students in each class	• Too many students in each class. Some students had no chance to do activities, play with exhibits and experiments.	1	4	1	-
5)	Less interaction with some exhibits	The bicycle was only for testing the materials for the wheel; participants could not ride it on the floor.	1	-	-	-
6)	Noisy experiment	• Participant did not like the noise of some science experiments such as a balloon bang. Moreover, participant felt annoyed by the rooster crowing from the Chicken Voice activity.	2	-	1	-
7)	Limits to working with others	In Tangram activity, some students in the team did not listen to other members' ideas, and some members had no chance to play tangram.	-	1	-	-
8)	Fear of interacting with some exhibits	Participant did not touch or interact with the Human Body Model because it was scary.	-	-	1	-
3.3 Outcome of participating in the Science Caravan						
1)	Enjoyment	• Had fun while interacting with exhibits and doing activities and experiments.	1	4	2	2
		• Had fun watching experiments in science show, such as the tin bomb, a squeezed bottle, a balloon bang.	3	2	1	2
2)	Knowledge and understanding	• Gained new knowledge about body balancing, human body, insects, science of sound and chemistry.	2	7	4	4

		• Gained better understanding of geometry by playing Tangram.	1	-	1	2
3)	Attitude and value	• Enhanced self-esteem by doing activity/finding answer independently.	1	-	-	-
		• Had good attitude toward NSM staff.	2	2	-	-
4)	Skills	• Practicing doing experiment/ activities, and using scientific method skills	3	2	3	-
		• Used experiment equipment (e.g., the circuit and microscope).	3	-	1	-
		• Practised communication skills.	1	-	-	-
		• Practised social skills and made new friends while participating in the Science Caravan.	1	-	-	-
5)	Behaviours and progression	• Studied more about interesting topics such as insects, fossils and dinosaurs	7	4	4	4
		• Shared new knowledge with family.	1	-	3	3
3.4 The needs of local young participants regarding Science Caravan development						
1)	Revisit	Science Caravan needs to visit again.	5	4	3	3
2)	New and more varieties activities/ more science games	Needs more new content and more activities such as cosmology, fossils and dinosaurs.	2	3	2	1
3)	More presents for participants	Needs more presents for participants.	-	3	1	1
4)	Extend time for participating in each activities	Needs to offer more time to do experiments/ activities/ exhibits.	-	1	2	-
5)	More activities for different groups	Needs different activities for primary school students and high school students	-	-	-	1

D.5: Coding analysis of the teacher interviews

Theme	Sub-theme		Coding (sample)	Count (N = response)			
				The Northeast	The North	The Centre	The South
1 Informal science learning experiences of young local people							
	1.1 Informal science learning settings						
	1)	Public library	Reading science books; Using computers and internet; Using Wi-Fi service	4	4	1	2
	2)	Home computer and internet	Searching science knowledge via science websites.	-	1	-	-
	3)	National park	Attending day camp in local national park.	6	4	2	3
	4)	Local aquarium	Visiting local aquarium.	-	1	-	-
	5)	Science Museum	Visiting NSM.	-	-	1	-
	6)	TK Park Mahasarakham	Visiting TK Park Mahasarakham.	1	-	-	-
	7)	Local water plant	Visiting local water plant to learn about water treatment.	-	-	-	2
	8)	Local power plant	Visiting local power plant to learn about power generation.	-	-	-	3
	9)	Local canned fruit factory	Visiting factory with parents who work in the factory. Students can learn how to use technology to produce canned fruit.	-	1	-	-
	1.2 Informal science learning resources						
	1)	Smart phone	Using smart phones to access scientific knowledge.	-	1	-	1
	2)	Website search engine	Using Google and YouTube.	2	-	-	-
	3)	Family	Getting help from parents for science homework.	-	-	-	2
	4)	Local wise men	Establishing special lectures from local wise men about traditional wisdom such as food preservation.	-	2	-	-
	1.3 Informal science learning event						
	1)	Science camp	Local schools worked together to create a science camp programme for their students.	-	-	3	1
	2)	Science competition	A science show competition was hosted by NSM.	-	-	-	1
	3)	Science festival	A science festival was hosted by a local university.	-	2	-	2
2. Factors affecting informal science learning experience for local young participants							

	2.1 Schools	• Main source of support for the visiting of informal science learning settings and events	-	-	2	1
		• Provider of informal science learning programmes such as science camps.	-	-	-	1
	2.2 Teachers	• Supporters of knowledge for students while visiting informal science learning settings.	-	-	-	1
		• Main source of learning resources. Students can ask teachers any science questions.	3	1	-	3
	2.3 Families	• Sometimes supporters of traditional belief. Some parents may not support students' science learning in school because scientific knowledge goes against their superstitious beliefs.	2	-	-	2
		• Parent supported their children's study such as helping children doing science homework	3	4	3	4
	2.4 Government	Provider of funding for promoting science education for local students.	1	1	1	1
	2.5 Other organisations					
	1) Local community	Promotes informal science learning that links with traditional wisdom.	-	-	-	2
	2) Local university	Promotes science learning via a science festival for students and science teaching workshops for teachers.	-	2	-	-
	3) Private company	Provides funding to support local students' visits to informal science learning settings.	-	-	-	3
	2.6 Student	Limits of reading and writing skill	-	-	-	2

		Limits of Scientific Knowledge background	-	-	-	2
3. Science Caravan and local young participants						
	3.1 Experience of involvement in the Science Caravan					
	1) Involved in the Science Caravan	Used to involve with the Science Caravan	3	4	1	-
	2) Never involved in the Science Caravan	Never engaged with the Science Caravan	2	1	4	5
	3.2 The reasons behind the determination to be involved in the Science Caravan					
	NSM	The NSM has great potential.	2	6	-	1
		The NSM belongs to the Ministry of Science and Technology.	1	-	-	-
	3.3 Teachers' expectations from the Science Caravan involvement					
	1) New scientific knowledge	Should provide new scientific knowledge for local students and teachers.	-	1	1	-
	2) Science hands-on exhibitions	Should offer hands-on exhibitions to help students have better understanding of science phenomena and theories.	5	4	1	4
	3) Motivation	Should encourage students' interest in science and technology.	1	-	3	-
	3.4 The outcome of the Science Caravan after involvement					
	1) Teachers	• Learned new teaching techniques.	1	5	8	3
		• Inspiration as to how even non-science teachers can teach science in school.	2	3	4	2
		• Obtained new knowledge and improved understanding.	1	-	-	-
	2) Students	• Obtained new scientific knowledge and deeper understanding of science phenomena.	6	4	4	6
		• Enjoyed the science experience.	2	2	2	2
		• Practised experiment skills.	4	3	1	-
		• Experienced a different learning atmosphere outside of school.	-	1	1	-
		• Developed social skills.	-	-	-	1

		• Improved attitude toward science subjects.	-	-	-	1
3.5 Teachers' perception toward the involvement in the Science Caravan						
1)	Positive attitude toward the Science caravan	• Feeling thankful that the Science Caravan visited school, as it offered more chances for student involvement.	-	1	-	-
		• Impressed with the NSM explainers' performance and teamwork.	-	-	1	-
		• Impressed with the science activities, which supported the science learning students had done in school.	-	-	-	1
2)	Limitations of the Science Caravan	• Short participation time for each activity	-	1	1	-
		• Too few activities	-	2	-	-
		• Too many students per class	1	1	1	1
		• Some activities inappropriate for some students (e.g., the Chicken Voice activity, which was too easy for the high school students).	2	-	1	3
3.6 The needs of teachers regarding the Science Caravan development						
1)	Annual visits		2	2	-	2
2)	Activities	• Limit the number of participants.	5	4	5	6
		• Develop new activities and more variety.	-	-	1	1
		• Offer more activities for different groups of participants.	1	1	2	5
		• Introduce more science topics, e.g., cosmology, life, chemistry.	1	-	1	1
		• Extend time for participating in each activity and visiting each location.	3	1	1	2
		• Explain any basic knowledge that participants need to know before doing activities to help them have better understanding.	-	-	1	-

3)	Evaluation	Evaluate the Science Caravan after finishing each location to promote further improvement and development.	-	-	1	-

D.6: Coding analysis of the NSM staff interviews

Theme	Sub-theme	Coding (sample)	Count (N = response)
1. Factors affecting informal science learning experiences of local young participants			
	Teachers	• Teachers are the main resource for promoting the science learning of local young participants.	1
		• Teachers encouraged participants to take part in the activities in the Science Caravan.	1
2. The Science Caravan and local young participants			
	2.1 Learning with science activities in the Science Caravan: Learning behaviours		
	1) Watching/ observing	• Watching exciting experiments. The Northeast participants preferred to watch or observe rather than doing directly.	4
		• Observing NSM staff doing experiment. Girls preferred to observe others doing activities before doing the activities themselves.	1
	2) Doing experiments/ activities	• Doing experiments/activities by themselves. Boys preferred to do experiments/activities themselves immediately.	5
		• Primary school students liked making the Chicken cup and playing the Chicken Voice by themselves.	1
	3) Using experiences to solve the problems	Using experiences of learning in school to participate in science activities	1
	2.2 Limits of learning science activities in the Science Caravan		
	1) Too many participants	Some participants had no chance to do some activities because of the number of participants involved with each activity.	2
	2) Language barriers (minority groups)	• Minority groups' different languages can be obstacles to learning in school and informal learning settings/events.	5
		• Science jargons are too difficult for primary school students; simple language should be used to explain/teach.	1
	3) Learning performance of participants	Participants had limited reading skills and knowledge backgrounds. Therefore, they learned to do activities/experiments more slowly than other urban participants.	5
	4) Communication skills of the explainer	Explainers had limited ability to explain the science experiments/activities to different groups within the audience (e.g., different age and gender groups).	1
	5) Limits of activities/ experiments	• Activities/experiments were not designed for broader groups. Some activities such as the Chicken voice were too easy for high school students.	2
		• Limited science equipment. Some equipment such as a Van de Graaff generator was unavailable, as it would be too easy to damage during travel. Therefore, local participants had no chance to see an experiment performed using the Van de Graaff generator.	1

	6)	Traditional belief/ superstition	Parents who believe in superstitions presented an obstacle to teaching science to local participants.	2
2.3 Outcome of participating in the Science Caravan				
	1)	Enjoyment, inspiration	• Had fun watching the science show.	7
			• Had fun doing experiments/activities.	6
			• Inspired students to study more science and technology.	1
			• Inspired students to be scientists/ science communicators.	2
			• Inspired teachers to create experiments from simple equipment such as kitchen materials.	6
	2)	Knowledge and understanding	• New scientific knowledge.	2
			• Better understanding of how science phenomena link with a science curriculum in a classroom.	1
	3)	Skills	• Skills for experiments/activities.	3
			• Skills in using experiment equipment.	2
	4)	Attitude	• Good attitude toward science as a subject.	4
			• Awareness about the importance of scientific knowledge related to daily life.	4
			• Better self-esteem among participants after they had to find the answers by themselves.	3
			• Good attitude toward the NSM staff and the Science Caravan.	1