# SUPPORTING FAMILY LEARNING IN THAILAND'S NATIONAL SCIENCE MUSEUM: DESIGN AND EVALUATION OF MOBILE TOOLS

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## Abstract

Science education researchers and practitioners become increasingly interested in the use of mobile tools to enhance science learning outside school. A number of related projects and initiatives have been launched in museum settings over the past decade. This study focuses on the integration of mobile learning into families' science museum experiences as a tool for enhancing family science learning. This thesis presents research undertaken with family visitors to The National Science Museum in Thailand (NSM). The research comprised three major activities: 1) a preliminary study to identify the family learning needs and desired support at the NSM; 2) the development of a mobile application for NSM family visitors; and 3) A comprehensive summative evaluation that used a range of evaluation methods to provide a deeper understanding of the impact of the mobile application on the family experience. The preliminary study included interviews with three groups of participants (museum staff, family visitors, and the mobile app developers). Data about family need and desired support and services were collected and analysed through Grounded theory (Glaser & Strauss, 1999). The content, structure and features of the mobile application were subsequently designed based on the requirements that emerged from the preliminary study. The application was created for both iOS and Android operating systems. Four main features of the application are *Exhibition highlights* which includes additional multimedia interpretation of some prominent exhibits, *Map and direction*, *Camera and QR code interface*, and the museum's *Events Calendar*. The summative evaluation focused on the impacts of the mobile application on the family experience, including learning outcomes and family engagement with exhibits. It included 1) usability evaluation of the mobile application; 2) evaluation of the family learning outcomes by applying the Generic Learning Outcomes (GLOs) framework; and 3) an analysis of video-based observations of family behaviours at an exhibit using Bitgood's attention-value model of visitor engagement (Bitgood, 2010).

Findings suggest that the app (a) significantly increased family dwell time, (b) provided an additional platform for family interactions, and (c) amplified learning outcomes. The study aspires to evidence the potential of mobile technology to enhance family learning in the science museum and to offer guidance for developing similar tools for families in other informal science learning contexts. The thesis concludes with a summary of the implications of this study and recommendations for further research.

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# CHAPTER 1 : INTRODUCTION

## 1.1 Introduction

The research presented here focuses on **supporting family learning in Thailand's national science museum through the design and evaluation of mobile tools.** This introductory chapter begins with an overview of the researcher's background and a historical account of how my interest in the area of family learning, science learning and mobile learning in the science museum grew. Next, the importance of science learning, of informal science learning, and of family learning and its role in science learning are highlighted, before moving on to summarise the current state of informal science learning in Thailand and of technology and mobile learning in museums and informal learning settings. The introduction concludes with an outline of the research questions and an outline of the structure of this thesis.

## 1.2 Researcher Background

I started my museum career at the National Science Museum, Thailand, in 1998, working as a science educator and science communicator. For over ten years before I started this research in 2010, I had been responsible for exhibition development and design, museum education, science activities and science education at the Museum. Accordingly, I had been exposed to various interactive exhibits that encourage self-directed learning. However, I was acutely aware that not all of them are effective. From time to time I was told by visitors, or found out myself through observing them, that they did not know how to interact with the exhibits or they interacted with them inappropriately, which greatly affected their learning experience.

Although there have been several evaluation studies on museum education in Europe, America and Australia, there was a lack of research in the Thai context that investigates what exactly visitors learn from those interactive exhibitions. We know that volunteer visitor assistants play an important role, however, the problem I have encountered for over a decade is that the number of volunteers has decreased dramatically while the number of visitors has been increasing year on year, resulting in a decrease of the volunteer to visitor ratio. The need for tools that can enhance visitors' self-learning at the exhibitions was pressing.

As mentioned above, visitor numbers have been growing annually. While the majority are school groups of all ages, the second largest visitor group is that of family visitors, which had been increasing dramatically in recent years. Prior to their visits, school groups were usually given exercises so students tend to seriously take notes from the display labels and gather other data during their visit. Compared to school groups, family groups seem more relaxed while visiting, as their visit is not driven by specific learning tasks. Despite that, both families and students tend to take photographs during their visits. As digital cameras and camera phones have become commonplace, it is typical to see museum visitors use their mobile phones to take pictures of exhibits, panels or take selfies. Based on my observations, I developed an interest in the devices that visitors carry with them while visiting. I thought it has a potential to be developed into something more helpful for visitor learning in the museum than simply being used as a camera. That is why I became interested in learning through mobile devices, which might be able to help visitors enhance their scientific knowledge at the Science Museum exhibitions. Moreover, today mobile learning devices and relevant technologies have been highly developed and, as a result, their educational potential has attracted considerable research interest. Therefore, I acknowledged the possibility and potentiality to develop a multimedia tool to be used on visitors' mobile devices to improve science communication in the museum exhibition setting for families. This tool aimed to allow visitors to use their own devices to improve their self-regulated learning about science. With this tool, it is possible to connect science museums especially in the Thai context with science communication and the use of mobile technology to enhance learning. The goal is to make the Museum an informal science education setting that is suitable and accessible for visitors of all ages.

The focus of my research is on family groups. Although the number of annual visitors in this group is smaller than that of school groups, family visits are voluntary unlike school visits, which are compulsory. In this case, family visitors have a 'free choice' learning experience, and their responses to this intervention would better reflect its desirability as well as effectiveness. The results will therefore benefit future studies on other visitor groups. More importantly, I think the use of mobile devices with family groups is effective and provides visitors with self-regulated learning from scientific exhibitions, while enabling continuous connection of the family groups with the Science Museum before, during and after their visits. Apart from providing an insight about visitors' complex learning experience with scientific exhibits, this study contributes to knowledge regarding the evaluation methods, the details of which will be discussed later in the thesis.

This research does not aim to replace human staff with mobile devices in learning assistance. Yet it hopes to provide an alternative, complementary assistant that maximises the effectiveness of science learning in the Science Museum among family visitors.

### 1.2.1 The Importance of Science Learning

All over the world, science and technology have become what is considered necessary knowledge for the public. Science helps us understand the secrets of our body, mind and our place in the world. However, there are often difficulties for people to access this body of knowledge. Public attitudes towards science and technology are generally positive but knowledge about science and technology is limited (Gregory & Miller, 1998: p.5). Science learning involves the building of conceptual knowledge and development of skills necessary to the scientific process such as observing, making predictions, planning experiments and generating conclusions based on evidence (Fenichel & Schweingruber, 2010). As science is one of the crucial parts of everyday life and by extension, part of society, one of the aims of learning science is to enable non-scientists to become familiar with scientific culture and aware that science is integral to their lives.

### 1.2.2 The Importance of Informal Science Learning

In order to understand informal science learning, it is useful to define the terms formal, non-formal and informal learning. According to the Organisation for Economic Co-operation and Development (OECD) and The United Nations Educational, Scientific and Cultural Organisation (UNESCO), formal, non-formal and informal learning can be distinguished according to the level of organisation and structure, conditions in which learning takes place, functionality and applicability of knowledge, skills and attitudes and level of evaluation and certification as a product of learning outcomes (OECD, n.d.; UNESCO Institute for Statistics, 2012).

Formal learning is intentional, organized and structured. It takes place within the education and training system of a country and results in formal certification and formal level of qualification. Non-formal learning is characterised by a deliberate choice of the person which takes place outside of the formal systems, but is usually intentional and organized such as learning through courses, workshops, seminars. Informal learning is never organized. This type of learning can be developed by any person, of activities in everyday situations and interactions that take place within them, within the context of work, family and leisure.

How are informal and formal science learning different, and what are the implications of their differences for science learners? Formal science learning, in general, is the learning process which happens in a classroom. It focuses on the knowledge of science which is controlled by curricula. Informal science learning refers to activities which take place outside the school environment, are not designed primarily for school learning or to be part of a school curriculum, and are undertaken voluntarily. They can be activities that take place at home, on the job among peers, in Science Centres and Science / Natural History Museums, after-school clubs, libraries, while watching science documentary programs on television, even while discussing at the dining table (Crane, 1994; Sawyer, 2006).

Everyone engages with some form of science learning in their everyday activities. From using our home appliances, to travelling from one place to another as well as the food and energy we consume, these can be counted as a product of scientific invention. Children in particular are required to learn science as a subject at school as it is a compulsory part of curricula around the world. However, the amount of time they spend learning science at school is less than the time spent learning science in other environments. This indicates that learning at school (formal learning) is not the only setting that provides opportunities to gain scientific knowledge (Fenichel & Schweingruber, 2010). Learning activities related to science can take place at home, amongst peers, inside science centres and science or natural history museums, after school clubs, libraries, while watching scientific documentary programs on television, or even while discussing issues at the dinner table (Crane, 1994; Sawyer, 2006). These and other informal science learning institutions play an important role not only in developing an understanding of science but also in providing enjoyment, generating further inquiry and formulating the sense that learning can be personally relevant and rewarding

(Fenichel & Schweingruber, 2010). Informal learning is also considered free choice learning, implying that the learner can choose if they want to learn or to leave, depending on their needs and interests (Dierking *et al.*, 2001) and contributing to a sense of control over learning.

Museums are considered one of the most popular places for informal learning about both culture and science. Science museums and science centres are effective informal science institutions that have been widely used as 'tools' to communicate science and technology to the public. These informal educational institutions produce various positive impacts: memorable learning experiences that could change people's attitudes and behaviours, an increase of visitors' knowledge and understanding of science, personal and social inspirations that enhance inter-generational learning and a development of trust and understanding between the public and the scientific community (ECSITE, 2008).

Bell, Lewenstein & Shouse (2009) highlight the cognitive, social, and cultural learning processes and outcomes involved in informal science learning. These derive from the learning setting, learner motivations and backgrounds, and learner expectations. Their ecological framework of informal science learning describes three aspects of learning that can be seen in all learning processes: people, places, and cultures; and uses these as a lens to examine learning environments and enable the researcher to identify various factors that are influential in the learning process.

The *people* lens, which is associated with purposes and outcomes of science learning in informal environments, includes the emergence of people's interests and motivations, knowledge, affective responses, and identity. As this lens describes "how people learn" it relates to people's decision making and also includes the influence of prior knowledge, level of knowledge background, and importance of metacognition (Bell, Lewenstein & Shouse, 2009). When humans develop intuitive ideas about the world and understand the environment around them this is usually associated with their prior knowledge. The role of prior knowledge is to support people's decision making and shape new meanings and understandings of how the world works. These developed ideas usually influence people's behaviours and assume an important role in learning and education.

Learning can be thought to occur within and across particular places. From a sociocultural perspective, the physical features, materials, and activities that relate to specific places has the ability to influence learning processes and outcomes. Learning is generally associated with particular places, artifacts, and also activities. In the areas of science learning these places can refer to scientific apparatuses such as microscopes, telescopes, or databases; specific places or locations related to a science learning event; and activities such as a demonstration or show which generates science learning processes and outcomes (Bell, Lewenstein & Shouse, 2009). The specific forms of science learning are associated with particular places, and people develop and learn science within these places in different ways.

People develop individual thinking and learning through their association with cultural practices. They develop specific skills, knowledge, commitments, and identity within their assigned or chosen community. This allows them to become proficient in the practices and values of this community. Interestingly, during the process of developing skills, knowledge, and identity with the community, people also influence these very same cultural systems with their own prior experiences and knowledge. The culture affects people's thinking and learning while individuals influence cultural groups; that is, they drive each other.

The cultural lens thus includes people's worldviews which they bring to a learning environment. The cultural lens therefore is likely to be part of cultural heritage and includes the way they understand the world and form their identity.

Bell, Lewenstein & Shouse (2009) also discuss six strands of science learning in informal settings. These strands can guide informal science learning institutions to create and provide science learning experiences to their publics through programmes and facilities. The strands include developing an interest in science, the understanding of science knowledge, engaging in scientific reasoning, reflecting on science, and engaging in scientific practice.

***Strand 1: Developing interest in science***

This strand is concerned with the motivation to learn science. It shows the goal of learners' experience based on excitement, interest, and motivation to learn or to do activities related to science, which allow learners to gain knowledge and experiences about the natural and physical world. It also addresses emotional engagement with it, signs of curiosity and willingness to continue their activity despite being confronted with challenging scientific ideas and procedures during their engagement.

***Strand 2: Understanding science knowledge***

This strand addresses people's desire to learn and understand the main scientific theories. It would generate understanding, remembering, and using the scientific concept for the activity. This strand also refers to the explanations, arguments, models, and facts related to science that are provided by the learners during the activity. It also points out the interrelation between scientific concepts and implementation of these scientific concepts to build up their own argument.

***Strand 3: Engagement in scientific reasoning***

This strand is concerned with using scientific knowledge as a tool for making decisions, asking and answering questions, and evaluating evidence. Learners can use scientific knowledge and skills to build their own models and explanations that enable them to manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. They can also construct statements, reasons, and support ideas to defend their argument with reliable evidence, can draw conclusions for their argument, and also for their work with scientific concepts.

***Strand 4: Reflecting on science***

For this strand, the learners' understanding of science is focused on a way of knowing. People can understand and realize that science is a way of knowing. The learners can understand how scientific knowledge is constructed and are concerned that this knowledge is dynamic. The ideas and concepts about science can be changed by new evidence and theories as well as the learners' sense of how his or her own thinking changes. This can provide a critical stance for political debate and public policy.

***Strand 5: Engaging in scientific practice***

The scientific practice is done by groups of people working in a social system. This scientific practice develops specific apparatus related to science, scientific processes, social practices, and data representations to complete procedures. The learners who are engaging in scientific practice in the community of science require knowledge and experiences of the language, tools, and core values. This strand focuses on how the learners in informal environments appreciate scientists' communication in the context of their work. The learners show willingness to participate with scientific activities and learn practices with others by using specific scientific language, such as experiment, control, and hypothesis, which enable them to explore and understand how scientific progress is made and how scientists conduct their work.

***Strand 6: Identifying with the scientific enterprise***

This last strand focuses on the assessment of learners in how the learners define themselves with respect to science and identify themselves as being comfortable to do science even though they are not professional scientists. This strand focuses on learners who identify themselves as science learners rather those who aim to be professional scientists. The learners can show they are comfortable with knowledgeable about, or interested in science for their hobbies, take an informed policy position, or refer to science or use scientific knowledge in their decisions when appropriate.

Bell, Lewenstein & Shouse (2009) analysis shows that informal science learning can be 'multi-stranded', taking place at different levels, as an interaction between people, place and culture. One particular 'institution' that is important both in the cultivation of science learning attitudes and propensities and the actual science learning practice, is the family.

### 1.2.3 The Importance of Family Learning and its Role in Science Learning

The importance of the social dimension of a museum learning experience is well established. Laetsch *et al*. (1980) point out that social interactions and information sharing at the exhibit can help form connections between the exhibit and the phenomena it represents. Blud (1990) also agrees that the interaction between group members is able to enhance cognitive processes through social behaviour. As the first educational institution that impacts on how people construct their knowledge, the family group as a unit of social interaction and learning in the museum is of particular interest. Families go to museums with a variety of purposes, ranging from entertainment to convenience and family traditions, and these are equally effective learning motivators (Ellenbogen, 2000; cited by Ash, 2003). There are research studies that point out that the learning impact of a visitor's museum experience is influenced by their various agendas for their museum visit (Dierking, 1989; Dierking & Falk, 1994; Falk, Moussouri & Coulson, 1998; Hilke, 1989; Hooper-Greenhill & Moussouri, 1999; McManus, 1994). During the museum visit, the family group works together and generates experiences through communication with the museum (Dierking *et al.*, 2001; McManus, 1994). They support each other to construct meaning through connecting their personal and sociocultural past with the physical context of the museum environment (Hooper-Greenhill & Moussouri, 1999). Understanding how the family visitor group's learning in science museums can be improved and enhanced is one of the museum's goals (Borun, Cleghom & Garfield, 1995; Diamond, 1986; Falk, 1991; Koran Jr. *et al*., 1988; McManus, 1987, 1994).

### 1.2.4 The Situation of Informal Science Learning in Thailand

Similar to the western world, the opportunities for informal science learning in Thailand are plentiful, taking place outside of the formal space of the classroom. Available to Thai people are over 800 libraries across the country together with a network of over 15 science museums and science centres located in big cities.

Museums have become popular among Thai people in recent years. Data from the National Statistics Office in Thailand in 2009 (National Statistical Office, 2009b) reported the average time that Thai people spent on social, cultural and recreational activities back in 2001 and showed that sports, exhibitions and museums were the most popular activities that Thai people participate in, spending on these an average of 1.8 hours per day. In 2004, the average time participants spent on these activities increased to 2 hours per day (National Statistical Office, 2009b) and recently increased to 2.96 hours per day in 2015 (National Statistical Office, 2016).

Science-related educational and documentary programmes and features on television, radio, newspapers and magazines also play a significant role in serving the knowledge and information needs of the public. Computers and the Internet are becoming massive channels of learning in Thailand. According to the recorded data by the National Statistics Office in 2008 on the means by which the public find out news and information about science and technology, television was ranked first as a tool to gain information about science at 77.9%. It was followed by newspapers, the Internet, radio, magazines and journals, science museums and science centres, and exhibitions (National Statistical Office, 2009a).

One of the reasons why science museums and science centres come after newspapers, the Internet, radio, and magazines may be that these mass media are easier to find and access in Thai society than science museums and science centres. Research on the public's interest in and awareness of science and technology in Thailand revealed that families prefer to spend their leisure time at shopping malls rather than museums (Hathayatham, 2005). Lack of public transportation to the museum was identified as a major obstacle. Additionally, as the study indicates, parents might assume that their children could gain more knowledge in the science museum setting when visiting with their school. However, existing research on how families learn science through exhibitions and how to enhance the family learning experience in science museums in Thailand is limited (Hathayatham, 2005).

### 1.2.5 The Situation of technology and mobile learning in the museum and informal setting

Museums, especially science museums and science centres, are among the most important resources of the body of knowledge that serve the mission to communicate science and technology in order to improve attitudes towards science and the public awareness of science and technology. Moreover science museums and science centres also are places to cultivate, educate and develop curiosity for every walk of life as life-long learning institutions (Massey, 1999: p.60).

Modern museums function not only as a place for displaying artefacts, but also as an environment for learning, relaxing, entertainment and education. As the agendas of museums cater for a variety of visitors, museums necessarily attempt to use many kinds of tools in order to serve their visitors' learning (Falk & Dierking, 2000). However, the content and information, which is displayed in exhibitions, sometimes limit visitor learning due to many conditions such as the space for information at the exhibits, the level of the language and the budget of the museum. These challenges may be hindrances for museums to achieve their aims. Research in recent year shows that information technologies (such as the Internet) have become a significant tool to provide valuable solutions to these problems and reach the aims of the museum.

To date, many technologies have been developed in museum settings, such as multimedia, animations, simulations, digital graphics, interactive projectors and the Internet. The main purpose is to enhance learning in museums through the museum's exhibits and activity programmes. Well designed and appropriately used digital media and devices can offer potential for enhancing visitor learning in museums (Falk & Dierking, 2008) when they are used for to expand the learning environment and to inspire and stimulate the curiosity of the visitors.

## 1.3 Motivation for this study

Over the past two decades, there have been many research studies which point towards technology's great potential for supporting and enhancing visitor learning experiences in the museum. The mobile technology has also expanded modes of interaction between visitors and the museum as well as among visitors themselves. Moreover, the technological tool potentially helps visitors engage with the museum prior to, during and after the visit. Additionally, the tool can be effectively and quickly managed and controlled by museum staff regarding information management and representation media.

Previous studies have focussed on their target audiences including school students, who visit museums to gain extra knowledge from what they learn in schools, and general visitors, whose purposes of visiting museums are varied. In order to broaden knowledge on this subject, it is worth investigating the effects of the use of mobile technology as a tool to support and enhance visitor learning, especially among family groups. It is also interesting to employ this technology along with different types of exhibits such as models, showcases and interactive displays in order to help visitors learn about complicated scientific concepts surrounding phenomena which cannot be easily observed. This is not an object-based form of representation and what impact this form of representation might create is an interesting question.

Interest in science learning outside the classroom has been rapidly and widely increasing, as is interest in the potential of mobile technology to support such learning. The research presented in this thesis focuses this line of research on family groups, whose unique social interactions both shape and are shaped by the museum visit. The purpose is to understand the impacts on family science learning of the integration of mobile technology within the family visit in the science museum.

This research thus addresses the research question:

1. What are the impacts of mobile learning tools on family learning in the science museum?
   1.1. How can we identify and assess these impacts?
   1.2. How can we design for these impacts?

## 1.4 Structure of the thesis

This thesis consists of eight chapters. Chapter 1, the introduction, covers the background of the thesis, the motivation for and purpose of this study and its objectives.

Chapter 2 constitutes the literature review, which comprises five parts. The first part reviews the theories of *Discovery learning*, *Constructivism*, and *Socio- Cultural Learning*. The review then provides the background to what roles different theories play in learning such as how learners create knowledge for themselves and how they learn through socialisation and from family members. The third part is a review of *Family Learning in the Science Museum*. This section gives a detailed overview of family learning contexts, from definitions to existing literatures on the influences of contexts on family learning. Some examples are behaviours of family members in museums, how they interact with one another within the family group as well as with exhibits and exhibitions in ways that are appropriate and helpful for effective family learning in museums. The fourth part discusses learning with mobile technologies in the museum. It helps shed light on the background of mobile learning from the history to the application of the mobile technologies and the studies of their effects when being used in museums to enhance visitor learning experience. The final part entitled 'Identifying Learning in the Museum' reviews relevant concepts and models, which include *the Contextual Model of Learning*, *the Generic Learning Outcomes* and *the Attention Value of Museum Visitor*. These three analytical models of museum learning are employed in this study to analyse family learning in the Museum.

Chapter 3 describes the research methodology used in the three phases of this study: the family learning needs analysis, the development of a mobile application (app) for families, and the summative evaluation. The methodology chapter aims to provide an explanation of the sampling method and its strategies used in conducting different activities in each part of the research process.

Chapter 4 describes the first phase of the study, which is a family learning needs analysis conducted in September 2012. The chapter begins with the methods, techniques, participants and procedures followed by the findings from interviews with three groups of stakeholders in this research as well as the analysis of family requirements and problems about their learning experience in the Science Museum. The last part of this chapter offers conclusions and suggestions drawn from the analysis for designing tools to improve family learning experience in museums using mobile applications.

The details about designing and choosing exhibits together with their functions and applications' features are included in Chapter 5.

The main study is presented in Chapter 6. It covers results from the three parts of the summative evaluation, which included usability evaluation, the evaluation of family learning outcomes, and a video-based observation of family engagement with exhibits.

Chapter 7 presents a discussion of the findings of the research, which illustrates relations, processes and roles of effective mobile application usage in the science museum during the family visit. The chapter then concludes the thesis with a list of suggestions for further study in related areas.

# CHAPTER 2 : THEORETICAL FRAMEWORK: FAMILY LEARNING IN THE SCIENCE MUSEUM

## 2.1 Introduction

The theoretical framework for this study is based on three main theoretical perspectives that serve as foundation for understanding family learning in the museum: constructivism, discovery learning, and socio-cultural learning. The departure point for establishing this theoretical framework is the definition of learning from the Museums, Libraries and Archives Council (2004):

> *Learning is a process of active engagement with experience. It is what people do when they want to make sense of the world. It may involve the development or deepening of skills, knowledge, understanding, awareness, values, ideas and feelings, or an increase in the capacity to reflect. Effective learning leads to change, development and the desire to learn more.*
>
> (Museums, Libraries and Archives Council, 2004)

This definition emphasises, on one hand, the diversity of the learning outcomes that may emerge from a museum experience and how they extend beyond cognitive gains; and on the other hand, it highlights the experiential nature of learning in the museum and the importance of learners making sense of such experiences, rather than simply 'absorbing' information.

Learning theories are important for any institution that wants to understand how people learn and how to facilitate their learning experiences effectively. Such theories are applicable not only to schools, but also to every place that provides learning opportunities, such as museums. The behaviours of people in learning places can be understood through the lens of learning theory, in order to better understanding how and why they learn in museums. In the article *Researching Learning in Museums and Galleries 1990-1999*, Hooper-Greenhill and Moussouri (1999) explain that learning can be facilitated by the design of physical spaces, particularly in the museum. Learning is driven by the experiences that the learner had before they explored the museum environment. Learning spaces are designed differently, depending on what types of knowledge, learners, and learning they are meant to facilitate. An understanding of learning theories is an understanding of the relationship between knowledge, learners, and learning. Such an understanding can inform why and how to design environments that support effective learning experiences.

Through an exploration of learning theory and how it plays out in the museum, this chapter lays out the theoretical framework of the thesis. Section 2.2 gives an overview of the historical development of learning theory as a consequence of philosophical enquiry into the nature of knowledge and a product of scientific observation and theorisation. Section 2.3 presents the foundations of Constructivism and the associated theories Discovery Learning and Sociocultural Learning in the context of museum education and learning. Section 2.4 further focuses on family learning in the museum, with a particular focus on science learning. Section 2.5 looks at frameworks for evaluating museum learning – specifically the Generic Learning Outcomes, the Contextual Model of Learning, and the Attention-Value Model of Engagement – how they relate with constructivism, and how they are adopted in this thesis to research family learning in science museums. Section 2.6 concludes the chapter with a recapitulation of the theoretical framework and how it is applied in the thesis.

## 2.2 Historical overview of learning theory

Many learning theories have been proposed in our attempt to understand the learning process, which has been the object of research for a long time. Philosophers have been preoccupied for centuries with how people learn, where knowledge comes from, and what the learning process is. The earliest philosophers to consider these issues, Plato and Aristotle, paid more attention to empirical evidence through observations of natural phenomena based on sensory experiences and the mind's working (Kelly, 2002). Centuries later, the behaviourists were the first to study the learning process scientifically. In the first half of the 20$^{th}$ century, Pavlov's, Watson's, Thorndike's and Skinner's work contributed to the development of theories of behavioural conditioning, which suggested that we learn new behaviours by establishing associations between stimuli in the environment and responses that lead to desirable effects. Pavlov (1927) was studying the digestive system of dogs, specifically the role of saliva. A few days into his experiments with feeding dogs he noticed that the dogs would start salivating as soon as they saw the food rather than as soon as they started eating. This led him to further experimentation, ringing a bell at the same time as presenting the food, and observed that after a few more days, the ringing of the bell was enough to make the dogs salivate, even if the actual food was not present. Based on Pavlov's experiments, Watson (1924) developed the theory of classical conditioning, proposing that learning is a process of conditioning: we start with an unconditioned stimulus (food) that causes an unconditioned response (salivation); we repeatedly present a neutral stimulus (ringing of the bell) that produces no response until it is associated with the unconditioned Stimulus; the subject then produced a new conditioned response (salivating) as a result of the conditioned stimulus (ringing of the bell). Skinner (1946) further developed Watson's theory by proposing that in fact the environment responses to our actions can lead to repeat behaviours, and distinguished such environmental responses into reinforcers (pleasant responses or the removal of unpleasant responses) and punishers (introduction of unpleasant responses).

Although behaviourist research is scientifically interesting and methodologically sound, it nevertheless tells us more about the effect of the repetition of a stimulus on behaviour rather than the actual processes of learning. Although behaviourism's premise that repetition leads to learning has found applications in areas such as television or radio advertising (Dierking, 2000b: p.22) and has permeated classroom environments for a long time, particularly in regard to behaviour management through rewards and penalties systems, the behaviourists' attention to the scientific method meant that learning had to be studied in artificial laboratory settings, which can be a hindrance to explaining more complicated forms of learning such as the learner's planning of two or three step actions to overcome problems in the real world (Dierking, 2000b).

Another aspect of learning that behaviourism struggled to account for are individual differences, where it offers limited insights. Individual differences, however, can impact the learning process significantly. As the real world is substantially different from the laboratory, behaviourism had obvious constraints in understanding and accounting for these differences. Contributing to the breaking from the behaviourist tradition in learning research was psychologist Jean Piaget's (1936) first systematic study of children's cognitive development. The main concept in Piaget's theory is that of a schema: an organizing framework that we construct through cognitive processing of objects, situations, ideas, etc. Encountering a chair, for example, will lead to the construction of a chair-schema: an object with four legs, a seat supported by the legs, and a straight back. Piaget argued that these schemata help us make sense of the world. When we encounter something new in our environment for which we have no working schema to match it against, we initiate a process of adaptation: we either modify an existing schema to fit the new information (assimilation), or we combine elements of existing schemata to generate a new schema that fits the new information (accommodation). Learning then is the process of recovering from the disequilibrium that is caused when encounter something that contradicts our existing schemata: this is the point where we question our beliefs and try out new ideas as we engage in assimilation and accommodation, which leads to a new, more knowledgeable state of equilibrium.

By shifting the emphasis from behavioural responses to stimuli to cognitive processing of information, Piaget showed that people learn from the data they perceived in their environment, and then process that data into information before generating knowledge (Durbin, 1996). This view of learning underpins Piaget's four stages of development, which describe the cognitive development of young people as a process that takes them through four developmental stages of cognitive ability (Durbin, 1996).

Sensory-motor is Piaget's first developmental stage, where children learn to adapt physically in response to their surroundings and the presence of their family. This stage is from birth to approximately 2 years old. The second stage, from year 2 to 7, is called preoperational. In this stage children are not yet able to make reasonable connections between cause and effect. While they do have the ability to recognise the past and imagine the future, they cannot distinguish reality from fantasy. The third stage is called concentrate operational and spans approximately from age 7 to 11. In this stage children have the ability for rational thinking and are able to distinguish reality and make links to their own experiences. The fourth and final developmental stage is called formal operational and occurs between approximately 11 and 14 years old. Piaget suggests that the brain of these young children has almost reached the developmental level of that of an adult. Children in this stage of development have abstract thinking capabilities and are able to rationally connect to reality just like adults. They also have the ability to link imagined possibilities to their knowledge, i.e. to experiment mentally.

Piaget explains that the average ages for each developmental stage can vary, and that the child's development will depend not only on their physical age, but also on the child's social environment (Durbin, 1996). She asserted that the interactions with the material and cultural environment can help children create meaning and advance through the stages of development.

Piaget's cognitive development theory focuses on how the brain develops in children and highlights the cognitive differences between children and adults. Cognitive development and intellectual ability, however, are not the only factors that affect learning. Prior attitudes and beliefs also play an important role in shaping what and how we learn (Dierking, 2000b), and these are shaped by the person's social context. In their 'active engagement with experience', individuals bring their intellectual capabilities and potential, their background knowledge, and also their personal history of social interactions. One theoretical model that explains how knowledge is produced when all these factors are taken into account is constructivism. The following section presents an overview of constructivism and the closely related learning theories Discovery Learning and Sociocultural learning.

### 2.2.1 Constructivism

Constructivism focuses on the individual and the meaning they construct themselves, based upon current and prior experience, knowledge, and personal interests. Constructivism is associated with active learning, learning through discovery and knowledge building, all of which relate to approaches and processes that promote learning by doing.

Each learner has individual attitudes towards and beliefs about the subject of their learning. In order to explore the world, they must be able to generate a sense of personal, genuine interest. Prior knowledge, experiences, and personal interest and motivation are factors that play a very important role in the individual's construction of meaning. *Constructivist Learning* emphasises exactly this: people's ability to construct knowledge on their own during the learning process, building on prior knowledge, experience, and interest.

Piaget's theory of cognitive development was further developed by Jerome Bruner (1966) into the constructivist learning theory. As explained above, constructivism works on the basis that when humans learn, they construct new knowledge from past knowledge and new experiences. Therefore, nothing is ever learned as a separate, single piece of knowledge in a vacuum; rather, new knowledge is always integrated with prior knowledge and subject to the individual's existing knowledge structures and frames of understanding. According to constructivism, learning highly relies on what the learner already knows and understands and new knowledge is added to these; therefore the learning of new knowledge should be an experience tailored to the individual learner.

Dewey (1944) viewed learning as a process that is grounded on real experience and action within the world. The learner gains new knowledge when they engage in situations in which they see the personal value of the experiences they entail. According to Dewey, inquiry is therefore an important part of learning, as the framing of the inquiry enables learners to frame the learning experience according to their personal perceptions of its value. Bruner's (1966) contribution to the concept of constructivism is the emphasis on learning as a process of active discovery that takes place in a social context. In the process of discovering knowledge, learners in essence construct meaning at a symbolic level, while this construction of meaning is scaffolded by the teacher who provides the necessary support (Bruner & Garton, 1978).

Vygotsky (1978) also emphasised the idea of learning in terms of interaction between the individual and society, an interaction which is facilitated by language and culture. His "zone of proximal development," where students solve problems beyond their actual developmental level under adult guidance or in collaboration with more capable peers, has many parallels with Bruner's notion of 'scaffolding' (see also section 2.2.3).

From Piaget and Dewey to Bruner and Vygotsky, constructivism developed into a learning theory that focuses on the learner and the meaning they construct based on their unique prior knowledge, experiences, and interests, and facilitated by their social and educational context. This implies that knowledge is actively constructed within the learner's mind as information that they receive is processed, interpreted and understood in the context of individual cognitive structures and social experiences (Fensham J., Gunstone & Richard T White, 1994; Hein, 2000).

Constructivism is often associated with pedagogic approaches that promote active learning, also known as learning by doing or '*discovery learning*'. With our focus on the science museum as learning context in this thesis, the exploration of *Discovery Learning* in the following section will assist in further understanding the learning processes that this research aims to support.

### 2.2.2 Discovery Learning

Discovery learning is a constructivist learning approach that is usually referred to as 'hands on' learning. Discovery learning places emphasis on active engagement through inquiry-based instructional designs that attempt to stimulate interactivity at both the physical and cognitive level. In discovery learning, the learner constructs their own new knowledge by actively engaging with various instructionally designed models and strategies of exploration of the world. Philosopher and educational reformer Jerome Bruner, who coined the term *discovery learning* in 1967, viewed learning as an active process. His idea was that in the learning process, students' experiences of the world are a crucial part. The concept of providing learners with active inquiry experiences through which they learn through discovery is similar to the ideas of other educational theorists of that time such as John Dewey (1859-1952), Jean Piaget (1896-1980) and Seymour Papert (1928-2016). Bicknell-Holmes & Hoffman (2000) explain that discovery learning emphasises the needs of the learner in its three core characteristics, which are: exploration through problem-solving, learner-centredness based on the learner's interests, and the integration of new knowledge into the learner's existing knowledge base. The combinations of these three characteristics make discovery learning different from traditional classroom education in a number of ways: first, in discovery learning students are actively engaged in processing new knowledge and information rather than passively receiving information; second, discovery learning places emphasis on the learning processes in the mind of the learners, instead of providing content and information for students to memorize; third, failure or trial and error play an important role in the discovery learning process; fourth, the opportunity of giving feedback, and discussion among the learners are a crucial part of discovery learning; and fifth, discovery learning provides opportunities for deeper understanding (Castronova, 2002).

Studies focusing on discovery learning (Bicknell-Holmes & Hoffman, 2000; Bruner, 1961; Castronova, 2002; Schank & Cleary, 1995) describe its advantages as follows:

*Discovery learning actively engages students in the learning process:*

In discovery learning, the learners use their own prior experiences and knowledge to voluntarily explore new knowledge. They can draw conclusions about problems, learn from exploring and interacting with the world around them through questioning, and curiosity drives their experimentations. Active engagement in the construction of knowledge in discovery learning provides students the opportunity to construct their own meaning rather than simply memorize the information given by someone (e.g. the teacher, or a book). This helps the students remember more of what they learned through discovery learning activities. It makes the learning more desirable and achievable.

*In discovery learning, students are motivated to participate:*

In discovery learning, the learners are encouraged to follow their own curiosity and to build knowledge following their own needs. This provides a positive environment for learning (Schank & Cleary, 1995) that invites learners to participate in learning activities.

*Discovery learning encourages autonomy and independence:*

Discovery learning promotes individual growth, as active engagement and intrinsic motivation are vital in helping learners to design their own acquisition of knowledge.

*Discovery learning promotes the development of creativity and problem-solving skills*:

The major tenant of discovery learning is to actively provide learners a sense of self-directedness and motivation to construct new concepts and ideas. The emphasis is on the learning of skills rather than the acquisition of factual knowledge. The learners are encouraged to stimulate their imagination in order to cope with the new situation. Problem- solving and creativity skills can thus be promoted during the process of formulating ideas and planning for action through exploration and discovery.

*Discovery learning provides opportunities for highly individualised learning experiences:*

Discovery learning experiences are tailored to the individual learner as the process of learning is designed by the learners themselves and knowledge is constructed within the individual learner's mind.

In contrast to the proponents of discovery learning, there are also critics of the approach (Kirschner, Sweller & Clark, 2006; Mayer, 2004) who claim that when the construction of knowledge relies mainly on the learner who is encouraged to build knowledge and discover information by following their own needs and curiosity, the learner might reach a cognitive overload situation where they are unable to structure and process the demands of activities that stretch beyond their limitations. Additionally, the main tenets of discovery learning, namely self- directedness and self- control, may result in misconceptions. Both these problems may go unnoticed by the teacher.

However, a meta-analysis by Alfieri, Brooks, Aldrich and Tenenbaum (2011) asserted that "unassisted discovery" can be improved in terms of effectiveness and failures due to cognitive overload. Misconceptions can be overcome by providing appropriate guidance in the form of worked examples, elicited explanations, scaffolding, and feedback. These findings reinforce the recommendations of Bruner (1961) for scaffolding the learner's construction of knowledge.

Discovery learning thus brings into focus the role of learner-teacher interactions and how they facilitate the learner's construction of meaning. Another theory that emphasises the role of the social interactions is Vygotsky's sociocultural theory of learning.

### 2.2.3 Socio-Cultural Learning Theory

Socio-cultural learning theory has been gaining recognition in the museum world as it focuses on how people learn within a social context (Ellenbogen, Luke & Dierking, 2004, 2007; Leinhardt, Crowley & Knutson, 2002; Schauble, Leinhardt & Martin, 1997). The key idea of this theory is that people's activities take place within their cultural contexts through social interactions that are facilitated by language and symbol systems, which are in turn shaped by the individual's and the community's historical development (Ash, 2003; Matusov & Rogoff, 1995; Sedzielarz, 2003). Learning is, then, a socially-mediated process.

The sociocultural perspectives of learning derive from the work of Vygotsky (1978) whose main idea was that social norms and regulations, symbolic tools (such as language), and structured social interactions, allow members of social groups and communities to construct meaning and advance learning within the community (Greeno, Collins & Resnick, 1996). Vygotsky believed that social structures and interactions within the community shape the development of understanding and learning. Falk and Dirking (2000) explain that, according to Vygotsky, social interactions are the most important process through which members of a community synthesize information and are led to new knowledge: learning originates in the community and is then internalized by the individual members.

The learning of language by young children is one example where we can see the impact of social interactions. Children learn the language of their community by recognizing the connection between words and the objects or actions which are expressed by adults within the community, as they hear the language spoken. Another example of the impact of social interactions is situations where students with different levels of background knowledge in the same class learn from each other through dialogue or discussions during class assignments. A student in this case will acquire information then synthetize it to construct new knowledge through the social interaction, i.e. through discussion, within the social context of the classroom. Golding's (2004 p.58) study of groups of adults with children (family groups) found that adults are able to assist the children to overcome problems though social interactions (verbal signals), assisting them to learn within what Vygotsky termed their Zone of Proximal Development. One person thus helps another person to develop an understanding of a new concept.

The Zone of Proximal Development was proposed by Lev Vygotsky (1896-1934) to describe the learner's ability to do or learn something with help from a more knowledgeable other. Vygotsky divided the learner's ability into three zones: the first zone contains what the learner can do or learn without help; the second zone contains what the learner cannot do or learn no matter how much help they receive; the third zone, called the zone of proximal development, lies between the other two zones and contains what the learner has the ability to achieve with help from more knowledgeable other. The guidance and support that the learner receives in the zone of proximal development can be seen as scaffolding that enhances and encourages individual learning. This concept can be used to describe the role of tools related to education and learning, as they provide experiences and information to enhance the learner's potential to succeed in their individual learning.

#### 2.2.4 Constructivist, Discovery and Socio-cultural learning in the Museum

When applied to formal educational settings, constructivism places emphasis on how learning happens over the relationship between learners and teachers (Fosnot, 2005). Hein (1991) outlines the main characteristics of a constructivist learning approach within the museum context:

- learning is an active process of constructing meaning from sensory input.
- through experience, people learn both about learning process and content from the exhibit and environment of the museum.
- learning happens in the mind, during the museum visit learners make meaning within their mind.
- language and learning are inextricably linked, learners shape meanings when they explore new knowledge through language and knowledge is transferred through language.
- learning is a social activity .
- learning is contextual in that we learn in relation to what we already know, and in relation to our beliefs and prejudices.
- learning does not happen in a vacuum, previous knowledge is a pre-requisite to learning.

- learning occurs over long periods of time, through repeated exposure and intellectual engagement.
- motivation is essential for learning.

In the context of science learning, constructivism has been discussed widely (Carr *et al.*, 1994; Driver *et al.*, 1994; Harlen, 1996; Osborne & Freyberg, 1985). This demonstrates the relevance of this theory to science learning institutions like science museums in respect to visitor learning of scientific constructs. In the informal science learning context, the past century has seen the growth of hands-on science museums and science centres which have spread across North American and European countries (Caulton, 1998: p.4). The role of the museum has shifted from focusing on displaying collections and archives to communicating, interpreting and engaging with their visitors (Hooper-Greenhill, 1994: p.4, p9, p34; Pedretti, 2007: p.122). The visitors' experiences in science museums and science centres have consequently been related with concepts of discovery learning and constructivist learning theories (Falk & Dierking, 2000; Hein, 1998: p.31). In these institutions, a '*Discovery Room*' or '*Discovery Centre*' is in part replacing the traditional exhibition in order to provide this kind of active, engaging experiences for visitors (Boyle, 2009; Falk & Dierking, 2000; Hooper-Greenhill, 1994; Pedretti, 2007). Here, visitors are encouraged to play, touch and manipulate participatory exhibits in order to explore the scientific phenomena and concepts they represent. By providing opportunities for active engagement and stimulating the process of investigation, science museums are hoping to spark the process through which their visitor will be able to 'learn'.

Discovery rooms and the concept of exploring new knowledge within the museum galleries emerged in the late 1960s and have since spread widely. The first place of the discovery centre was the Exploratorium in San Francisco in the United States, which in 1969 was one of the first science museums to implement the concept of a hands on exhibition (Boyle, 2009). The Exploratorium, which opened to the public in 1969, was house to some six hundred interactive exhibits. The exhibits illustrate scientific phenomena on Physics, Mathematics, and Life Sciences. This new kind of museum, at that time, engaged visitors in a relaxing environment with hands-on exhibits. The Exploratorium used explainers, human staff, who set up the exhibits and assisted the visitors (Pizzey, 1987a) as can be seen in figure 2.1. In 1981, the UK's Science Museum in London opened the Launch Pad gallery, which exhibits basic concepts of science through experimental displays and touchable, interactive exhibits (Boyle, 2009). The prominent characteristic of this gallery is the use of technology alongside displays to engage visitors in exploring scientific phenomena. It intends to provide an experience rather than interpretation of the objects (Pizzey, 1987a) as can be seen in Figure 2.2. Constructivist learning was utilised as a framework for structuring exhibitions and programs in these institutions, particularly in exhibitions that targeted children (Falk & Dierking, 2000; Hein, 1998), and it thus become a widely embraced educational approach in science museums.


*Figure 2.1 The cavernous interior houses over 600 individual exhibits (Pizzey, 1987b: p. 7). The hands-on exhibits at the Exploratorium California, United State of America.*

*Figure 2.2 The view across Launch Pad from the entrance (Pizzey, 1987c: p.23).*
*The interactive exhibits at Launch Pad, Science Museum London.*

The main case study in this research is based in the National Science Museum (NSM), Thailand. Exhibitions at the NSM, as in other science museums across the world, aim to stimulate experiences that actively engage visitors and provide learning opportunities within the museum's galleries. The NSM's galleries include different kinds of display methods and media such as manipulable models, experimental exhibits, text panels and graphic labels (a fuller description of the NSM and its galleries can be found in Chapter 3). It thus offers visitors the opportunity to touch, play with and manipulate exhibits according to their own needs and learning approaches. The NSM is hoping that providing these opportunities for active engagement leads visitors to learn and understand the concepts of science.

This thesis focuses on one particular visitor group: families. The following sections will examine family learning in the context of the science museum framed by analytical models of museum learning, to provide a clearer view of how constructivist and discovery learning theories apply to family learning in the museum. The relevance of constructivism, discovery learning and sociocultural learning to the visitor experience is highlighted in Falk and Dirking's (2002) contextual model of learning. In this model, learning is shaped by the individual, the surrounding physical environment, and the other people around them, i.e. the personal context, the physical context, and the sociocultural context of the learning experience. It means that people learn in and through interaction with others, under the constraints and opportunities of the physical and social environments (Falk & Dierking, 2002, 2013).

## 2.3 Family learning in the Science Museum

### 2.3.1 Family as a context for learning

Family groups feature prominently in visitor studies literature (see for example – Ash, 2003: p.138; Blud, 1990: p.43; Borun, Cleghom & Garfield, 1995: p.263; Dierking, 1989: p.9; Dierking & Falk, 1994: p.57; Ellenbogen, Luke & Dierking, 2007: p.17; Henderson & Watts, 2000: p.41; McManus, 1987: p.263; Wood, 1996: p.77). A family unit is a child's first and foremost social and educational institution. It comprises individuals of different genders and ages, each with different intellectual abilities and attentional capacities, a mix of physical limitations, and a range of background experiences. Families are a significant visitor group, and this variability of their make-up presents museum researchers and practitioners with challenges. In order to optimise museum services and to shape museum provision to successfully support family visits, it is imperative to understand how families learn in museums and other informal settings (Borun, Cleghom & Garfield, 1995; Wood, 1996).

Research in the area of family learning in museums began in the mid 1970s and during the past four decades literature expanded to generate a detailed view of how families learn in and from museums. This section briefly reviews this literature to tease out our understanding of the family learning process in and from museums. We will first look at what are the characteristics of a family group, and then move on to examine what research says about the reasons why families visit museums, what family experiences in museums look like, how families learn in museums, and how we might assess family learning in the museum.

### 2.3.2 Families in the museum

The term '*family*' can mean different things in different cultures and countries. A family might include parents, children, grandparents, aunts, uncles, nieces, cousins, etc.; or it might only include parent/s and child/ren, with all variations in between. This research takes a broad definition of '*family*' to allow us to include the diversity of family groups in the museum's educational provision (Borun, Cleghom & Garfield, 1995). In the US, the make-up of families in the last four decades of the 20th century changed from the nuclear family that typically comprised two parents and two to five children, to blended families of various sizes ranging from single-parent families to remarried families, extended families, and co-parented families (Butler & Sussman, 1989; Dierking, 1989). A common characteristic of all types of family groups, however, is that they are multigenerational. Most studies of family groups in museum settings define a family group as a social group which comprises at least one adult and one child, and may also comprise people who are associated through kinship, residence, or other close personal association, allowing for an inclusive understanding of "family" (Borun, 2008: p.6; Borun, Cleghom & Garfield, 1995: p.262; Dierking & Falk, 1994: p.57).

In this study, we interpret the term "family" in the same way as do Falk and Dierking (2000). The term refers to "an intergenerational group of adults and children who self-define themselves as family" (Falk & Dierking, 2000: p.110). In the context of the National Science Museum, Thailand, we thus define a visiting family as a group of visitors that comprises at least one child aged between 6 and 12 years old, and at least one adult, bonded together in a family relationship. The reason for focusing on children of this age range is that children in Thailand start their primary school at the age of six and during primary education (between the ages of 6 and 12), children learn about science as one of the compulsory subjects at school. Additionally, many of the NSM's exhibits and contents are able to connect and relate to basic science curricula in primary school, so the children in this age range are presumed to be able to remember, recognize or understand some of the scientific terms and concepts provided in the museum. However, Serrell (1996) stated that most of the explanations in the museum's text panels are designed for an average reding age of 12 years old (Serrell, 1996). This means that when entering the museum gallery, children under 12 are not expected to read or comprehend the museum's texts on display by themselves. In this case, their parents could act as supporters, reading and interpreting such texts for their children as part of the family learning in the museum context – an act that presumably keeps the family group closer during their visit.

### 2.3.3 Family learning in the museum

Dierking *et al*. (2001) define family learning as the "process that incorporates the social bonds between relatives and the family's experience with objects, ideas and situations, becoming in essence, the family narrative" (Dierking *et al.*, 2001). Families use museums as places in which they can play, talk and learn from each other (Ash, 2003), and develop knowledge as they do family activities (Ellenbogen, Luke & Dierking, 2007).

There are many visitor studies and extensive research done in the area of family learning in museums and other informal learning institutes in Europe and in North America during the past two decades. According to Dierking & Falk (1994); as cited by Borun, Cleghom & Garfield, (1995) the focus on family research has been divided between family behaviour in general, family group interactions, time allocation, and family agenda issues on one hand; and research that investigates family learning in informal science settings on the other. Most research studies aim to understand this intergenerational visitor group's behaviour in order to improve and enhance the learning experiences of the family (Borun, Cleghom & Garfield, 1995; Diamond, 1986; Falk, 1991; Koran Jr. *et al.*, 1988; McManus, 1987, 1994). This section summarises the main findings of this research to date.

**Family learning in the museum is a social activity. The family group works together to build up a family experience of communication with the museum** (Dierking *et al.*, 2001; McManus, 1994). The interactive model proposed by Falk & Dierking (1992) considers the family museum experience holistically, suggesting that visitors (families) bring with them the personal and sociocultural context and interact with the physical context of the museum environment in order to construct meaning: 'whatever the visitor does attend to is filtered through the personal context, mediated by the social context, and embedded within the physical context' (Hooper-Greenhill & Moussouri, 1999).

**Family learning in museums involves coordination of activity and responsiveness**. Borun (2002) asserts that each family brings their unique culture, shared knowledge, experiences, and expectations to the museum. Families also bring a rich background of prior knowledge and experience to their visits (Borun, Chambers & Cleghorn, 1996; Ellenbogen, Luke & Dierking, 2007). The interactions between adults and children in a family group can vary from playful to very didactic (Borun, Chambers & Cleghorn, 1996; Diamond, 1986). According to Hilke (1989) and Diamond (1986), family visitors demonstrate learning support approaches during the museum visit such as acquiring, distributing or transferring, and relating exhibit information with prior or existing experiences. Verbal and nonverbal patterns of learning behaviour have been described by Borun, Chambers & Cleghorn (1996) and Diamond (1986). Diamond (1986) and McManus (1994) also indicated the differences in behavioural patterns among family members. For example, parents usually look at graphics panels, read, show, and tell their children; while children prefer to interact with the exhibits. McManus (1994) categorised types of social groups and observed and described differences in their behaviours; and found that adults modify their performance and behaviour to suit the children. The groups with children had longer conversations and stayed at the exhibits longer than groups without children (McManus, 1987-1988; cited by Borun, Cleghom & Garfield, 1995).

**Family learning in the museum continues to develop long after the visit.** The learning experience of the family is instigated by the social interactions that take place during the visit, and lasts long after the visit (Anderson, Storksdieck & Spock, 2007; Borun, Chambers & Cleghorn, 1996). Discussions about information and knowledge between family members does not only occur at the moment of experiencing an exhibition, but can take place any time in the days, weeks, or even months after the museum experience (Anderson, Storksdieck & Spock, 2007; Borun, 2002; Borun, Chambers & Cleghorn, 1996; Stevenson, 1991).

**Motivation and family agenda are important factors for family learning in the museum**. Visiting a museum is a free choice activity for families. What motivates a family visit, and what are the family's objectives for their visit, are crucial factors that shape family learning. Families visit museums with multiple goals that vary from entertainment to convenience to family traditions, and these can motivate learning equally effectively (Ellenbogen, 2000; cited by Ash, 2003). Families have agendas for their museum visits (Dierking, 1989; Dierking & Falk, 1994; Falk, Moussouri & Coulson, 1998; Hilke, 1989; Hooper-Greenhill & Moussouri, 1999; McManus, 1994). These agendas directly influence the learning impacts of the museum experience (Ellenbogen op.cit.).

### 2.3.4 Supporting family learning in the museum

Visitor studies in the West have not only developed our knowledge and understanding of how families learn in the museum, but have also endeavoured to develop tools for enhancing and encouraging such socio-cultural group learning in the museum. A short overview of these tools follows.

In 1996, a group of researchers in the Philadelphia/Camden Informal Science Education Collaborative (PISEC) led by Minda Borun investigated family learning in museums, and introduced seven principles of successful use of interactive science exhibitions for learning by multi-age groups such as families. These principles, expressed as exhibit characteristics, are: Multi-sided, Multi-user, Accessible, Multi-outcome, Multi-modal, Readable and Relevant (Borun *et al.*, 1997).

The hands-on aspect of the experience is particularly pertinent to family learning. Henderson & Watts (2000) developed an interactive gallery for children and families called 'ArtQuest' where a family group can share and interact together. These areas provided the family with opportunities to touch and examine objects, documents, and other materials in order to enable and enhance their understanding of a museum topic (Henderson & Watts, 2000).

Effective for family learning appears to be multi-level activities. The 'Families Exploring Science Together' (FEST) project was launched in 2000 as a collaboration between four science institutions in Philadelphia, US—the New Jersey State Aquarium, the Academy of Natural Sciences, the Franklin Institute Science Museum, and the Zoological Society of Philadelphia. The purpose of FEST was to increase parental involvement in the science education of their children through multi-level science activities for children and their parents. The project consisted of five components: Orientation Program, Family Science Events, Family Science Workshops, Special Project Series, and FEST Family Newsletter. Summative qualitative and quantitative evaluations of the project indicated the positive impact on family science learning (Dierking *et al.*, 2005).

Finally, Dierking *et al*. (2001) asserted that technology-based experiences in exhibitions can encourage and facilitate social interaction. Mobile technologies in particular seem to resonate well with the characteristics of the museum environment and the visitor experience (Reynolds, Speight & Walker, 2009). However, our understanding of how families actually use technology in museums is limited (Dierking *et al.*, 2001).

## 2.4 Learning with mobile technologies in the museum

### 2.4.1 What is mobile learning?

Mobile learning is an emerging and dramatically growing area of education and learning not only in schools, colleges, and universities but also in the work place and in leisure. Mobile informal learning has appealed to the interest of researchers and practitioners, particularly in the area of education (Elliston & FitzGerald, 2012; Pachler, Bachmair & Cook, 2009).

Early definitions of mobile learning focused on the use of mobile devices in the processes of education and learning (see e.g. Quinn 2000, Harris 2001, Wood 2003) – in other words, they focused on the mobility of the technological learning tools. As the field matured, the focus shifted to account for the mobility of the learner (Vavoula *et al.*, 2005). Traxler (2007 cited by Pachler, Bachmair & Cook, 2009) noted that mobile learning is learning that used to be delivered "just-in-case" and can now be delivered "just-in-time", "just enough" and "just-for-me", emphasizing the situational and personal nature of mobile learning, and echoing Laurillard's (2007; cited by Pachler, Bachmair & Cook, 2009) definition as "digitally-facilitated, site-specific learning". Sharples, Taylor & Vavoula (2007) described mobile learning as 'the processes of coming to know through conversations and explorations across multiple contexts amongst people and personal interactive technologies'. Similarly, Pachler, Bachmair & Cook (2009) understand mobile learning as the process of gaining the necessary knowledge and being able to operate across new and changing contexts and learning spaces.

These definitions indicate that the main characteristic of mobile informal learning is the individual's personal interest in free-choice learning, taking advantage of mobile, portable, technology and seizing control of their learning needs and of their learning process, within and outside their usual learning environments.

### 2.4.2 How do people learn with mobile devices in museums?

Mobile learning can spread the opportunities for science learning outside the school environment (Vavoula *et al.*, 2005). A number of mobile learning projects have been launched in museum settings. Among the first ones were the TATE Modern's use of Personal Digital Assistants (PDAs, a new mobile technology at that time) and wireless network equipment to provide a multimedia guide tour of its gallery in 2002-3. This project demonstrated that multimedia content delivery by PDAs had the ability to enhance visitors' experiences, despite the technical and physical limitations of the device and the location specific content delivery (Vavoula *et al.*, 2005).

Scruton (2005) described the benefits of using mobile phones in the Fitzwilliam Museum, where they helped visitors understand more and access a wider range of information in the museum, without having to disturb the displays (and the visitors) by including large text panels among the paintings.

The San Francisco Exploratorium used location-identification technology (RFID-Radio-Frequency Identification) to deliver content about the exhibits to mobile devices. The conclusion from the three-year evaluation indicated that these technologies have massive potential for improving visitor learning in museums. However, the drawbacks of having to learn a novel interface and the visitors' concerns about their privacy were major barriers of this project (Hsi & Fait, 2005).

The MyArtSpace project used multimedia mobile phones to deliver an interactive service that enabled visitors of galleries and museums to build their own virtual collections and galleries online with their mobile phones. Evaluations of the pre-visit, on-visit and post-visit experience of school groups using the service in three museums gained positive feedback from users, including museum educators (Vavoula & Sharples, 2009).

O'Hara *et al*. (2007) described visitor experiences with location-aware technology at the London Zoo. Children and parents worked together using mobile camera phones to collect information about animals in the zoo. Information was collected using 2-dimensional (2D) barcodes displayed outside animal enclosures. Evaluations of the service found that adults had difficulties in using the camera phones to read barcodes and access information during the visit; while children were able to use the phones, comparing and observing content. Moreover, children were keen to engage and complete their content collection during the visit.

Many novel technologies including mixed media, animations, simulations, and the Internet have been applied in museum settings in order to enhance learning in museums through exhibitions, displays, mobile audio and multimedia tours, and websites. Falk & Dierking (2008) argue that 'well designed and wisely used' digital media have the potential to enhance visitor interaction and learning in museums, so long as we ensure that they are used to create an environment that inspires and provokes curiosity and understanding between visitors with varying backgrounds, knowledge levels, and interests.

Tallon (2008) argues that mobile devices and digital technologies in general have the ability to be tools that enhance and transform the visitor's experience in the museum, and can be used to extend the reach of the museum beyond the limitations of its location and object display capacity, and to integrate the contributions of the visitors themselves to the museum's meaning making activity. However, Falk & Dierking (2008) warn that these technologies can enhance visitor learning only when they are suited to the visitors' interests, motivations, and prior experiences. They also suggest that, given the complexity of the museum experience, good design of digital media tools needs to take into account not only the physical but also the visitor's personal and sociocultural contexts.

In conclusion, during the past decade, many research studies in the West have illustrated the potential of using mobile technologies to support and enhance museum visitors' learning experiences, enabling interactions not only among visitors but also between visitors and the museum. By using mobile devices, visitors are encouraged to engage with the museum before, during, and after their visit. However, most of the studies were aimed at student groups and general visitors. In order to expand the knowledge in this field, therefore it is worthwhile to explore more about the impact of using mobile technology to support family learning in museums, which is a unique social interaction group.

## 2.5 Identifying learning in the Museum

Museums are sites that serve various purposes – relaxation, enjoyment, learning, among others. It is important for museum staff to understand how museums can maximize their values. One common motivation for visiting a museum is learning. Museums have become one of the most popular places where people learn outside the classroom. However, learning in museums differs from formal learning in classrooms; there are no teachers, examinations, homework or expectations. In formal educational institutions, people learn from a set curriculum and with certain objectives against which they are tested. After they achieve one objective they might need to achieve another, at a higher level.

Learning in schools – formal learning – is a process which purposefully differs from informal learning – learning outside the classroom. Learning in the museum is informal; people learn for their own interests and this shapes the meaning they construct from exhibits, which is personally relevant and meaningful. There is no compulsory examination after a visit to a museum. The knowledge gained from museums is diverse and allows free choice. Visitors have to make their own decisions to design the route they prefer for learning, and have the freedom to learn or to ignore the information displayed at the exhibition.

Museums are places that are open to the public and this means that museums serve both formal groups, such as school groups and professional groups, and also general visitors including family groups, individuals, or friendship/social groups. The school field trip to the museum has placed the museum as an institute supporting formal education. Much of the content in the museum is related to school curricula. Visiting the museum can enrich text book topics and illustrate them with real objects and offer real experiences in the exhibition or gallery. For example, students can see and learn about history from museum collections which are related to their subjects in the classroom. Moreover, many museums provide educational programs that support their school group visitors' formal education. For general visitors, visiting a museum plays an important role in supporting informal education. They may be learning in museums while pursuing a hobby, relaxing, enjoying themselves or visiting the museum out of simple curiosity. Sometimes, visitors might not feel that they have learnt much from the exhibition, although they were in fact learning while enjoying the visit.

People, including museum visitors, have their own learning preferences and these vary. They have different ways to learn: some people prefer learning from reading while others like to learn from doing activities with other members, or some prefer learning from interacting with the exhibits. However, it is sometimes difficult to notice that learning has happened at the time of the visit. Learning can happen at the exhibition during the visit or take a shorter or longer time to manifest after the site visit.

Museums offer a variety of sources of knowledge: books, magazines, leaflets, radio, posters, or websites, in order that diverse visitors can gain access to their favourite knowledge formats. As education features in museum missions, museums need to know what and how people learn and why people choose to learn from and through their museum visits. Three analytic frameworks of museum learning which have been developed with this objective in mind are examined below: *the Contextual Model of Learning*, *Generic Learning Outcomes*, and *the Visitor Attention Value model*.

### 2.5.1 Contextual model of learning

The contextual model of learning is a model that enables us to understand the factors that influence the museum experience of the visitors. The learning of individual people each time is different. Understanding what factors influence visitor's experiences and learning in the museum is necessary for museum professionals. Museums and other informal learning settings need to prepare and offer learning experiences that suit both the visitor's agenda and the museum's goals.

The museum experience can be understood when all three contexts – personal, sociocultural and physical – are considered together, as the whole is greater than the sum of the parts (Falk & Dierking, 2013).

#### The Personal Context

The personal context is unique: each person's existing knowledge and experiences are varied and different. A person's interpretation, understanding and experience of one thing is therefore not necessarily the same for another person and does not give the same result. The personal context includes the level of development, purpose, and learning preferences. It also includes differences in personal interests, attitudes, and motivations for the museum visit. Such personal factors influence what kinds of experience a visitor is looking for and shape their needs. They are the things that the visitor brings to the museum and, crucially, are what visitors will evaluate their museum experience against.

Personal context thus enables us to recognise and understand who does or does not visit the museum and allows us to understand how visitors engage and learn in the museum. Families constitute a very special visitor group, in that a good proportion of that personal context is shared between family members. Although individual differences remain, for example with respect to learning preferences, the family group has nevertheless a common framework of past shared experiences that, to some degree, defines each member's personal context.

**The Sociocultural Context**

Our sociocultural environment shapes our development of thinking, practices, beliefs, values, customs, language, and skills. Differences in cultural background result in a diversity of museum experiences, even when two people visit the same museum and interact with the same objects. The thinking, beliefs, practices, values, and attitudes that are inculcated by each a social group in a specific culture result in different ways of defining the world and are thus important factors to consider in museum communication.

Additionally, the social context of the visit itself – with whom one visits and socially interacts – strongly influences the visit experience: whether a visitor comes to the museum alone or in a friend or family group, and how they interact with other visitors or with museum staff during their visit, can result in very different experiences. The social context allows us to better understand and recognise the diversity of visitor's behaviours.

The social interactions within a family group are particularly important for family science learning. Through these interactions adults in the family can bring museum content into the child's zone of proximal development, and assume the role of the 'more knowledgeable other' who can help them grasp that content. Members in the family group exhibit behaviours for other family members to copy or study, for example when an adult demonstrates to a child how to interact with an exhibit. Social interactions within the family are therefore an integral and very significant part of the family visit.

**The Physical Context**

The physical context of the museum includes its architecture, construction, building, landscape, environment, objects, artefacts, exhibits, and also the atmosphere and the feelings that it triggers. The physical layout strongly influences how visitors move through the museum, the sequence in which they view exhibits and, therefore, the sequence in which they encounter concepts and ideas. The arrangement of objects, architectural features, and services also influence how long visitors stay in a location and, therefore, the length and depth of their interactions with exhibits. Moreover, the physical context also impacts on what visitors remember after their visit. The smell of a specify place in the botanic garden influences time spent within that place and provides, sometimes, a positive recollection after the visit. A broken exhibit can provide negative memories for the visitor. The light and colour of the exhibition and its environment can remind visitors after they return home. The distinction between various kinds of learning settings, such as historical museums, science museums, art galleries, botanic gardens, or zoos are derived from elements of the physical context, such as the architecture, the exhibit displays, the ambience and the environment.

For family groups allowing space to be together is important: exhibit spaces that allow the whole family to gather around, look and interact at the same time, and cater for simultaneous use by people of various physical and cognitive abilities, can facilitate the family visit.

**Time**

Time plays a crucial role as a fourth dimension of the model. To understand the museum experiences requires an examination over a period of time longer than the visit itself. In the contextual model, time makes the visit a dynamic, situation-specific system (Falk & Dierking, 2013). Each visit context is generated and changed continuously by the visitor. The visitor experience is continuously re-constructed through interactions between the personal, sociocultural, and physical contexts.

The museum experience, therefore, is constructed over time as the individual moves through their sociocultural and physical world. Considering these contexts over time, the contextual model of learning helps us better understand the choices visitors make during their visit.

Adding a time dimension aligns the contextual model of learning with constructivism: prior experience as shaped by the visitor's personal and sociocultural contexts have led to a state of equilibrium; the process of assimilating or accommodating the new information encountered in the museum might not be completed during the visit, and might require additional experiences in order to be completed. The new or modified schemata or mental models that emerge will serve to assimilate or accommodate information that is encountered in the future. The museum experience provides some but not all blocks for the visitor's construction of knowledge. For families, this concept of learning over time is particularly important, as it allows a holistic view of family life as a context of continuous meaning making.

The Contextual Model of Learning emphasizes the diversity of visitors and suggests a useful set of factors that might influence learning, and which are therefore useful to consider when evaluating museum learning (Falk & Storksdieck, 2005).

### 2.5.2 Generic Learning Outcomes (GLOs)

In formal education, the way to investigate how much people learn from the classroom is to simply look at scores in examinations taken by learners, which are the main evidence of progress in learning in the class in relation to the objectives of the curriculum. Formal testing as it happens in the classroom is difficult to apply within informal learning institutions like museums. As the museum is a public institution, open to all, which provides free choice of learning to its visitors, and as these visitors come in to the museum with diverse backgrounds and learning starting points, it is not feasible to devise tests that will measure everyone's learning. However, learning does happen in the museum and it is important to find evidence of it.

Learning outcomes in museums vary. They may include the construction of new knowledge or development of further understanding, the development of new skills, finding a new or different way to create something or think about something. Sometimes people visit museums in order to reinforce knowledge that they already have, in which case the learning outcome is increased confidence after the visit. Such learning outcomes are difficult to detect, let alone assess.

What should we be seeking evidence of, then, when evaluating learning experiences in museums? Learning outcomes which result from experiences in this kind of environment do not come with concrete evidence, such as that which is found in formal learning environments ('hard outcomes') like scores from the examinations and tests or demonstrations of skill. The learning outcomes that emerge from informal learning environments are therefore defined as 'soft outcomes' that include the attitudes, values, emotions, and beliefs of visitors (Hooper-Greenhill *et al.*, 2003). Also these soft outcomes are difficult to measure.

The Generic Learning Outcomes (GLOs) framework was developed to enable museums to capture learning outcomes for their visitors. The framework focuses on learning outcomes that are not only generated but also articulated by the learners themselves. Learning outcomes can be defined as the result of learning experience that relates to an individual, and can manifest in the short-term or long-term, i.e. they might manifest during the visit or they might take time to develop after a visit. For example, people exploring an exhibition about new technology of fuel cells today, might not understand the new knowledge gained at the time, but they might just remember some of the information and understand it when they encounter this subject in the future in a different context.

The GLOs reveal the diversity of learning in museums, libraries, and archives and provide a methodology for capturing evidence of museum learning. The framework comprises five categories of learning outcomes that convey the richness and depth of learning in museums and enable museums to get a bigger picture of their learning impact (Hooper-Greenhill *et al.*, 2003). These five categories are:

***Knowledge and understanding***: visitors show evidence that they have learned a new piece of knowledge or developed their understanding of a concept or idea. Knowledge about what a museum, library or archive is and how it operates also falls under this category, as is the making of connections and realization of relationships between things they already knew.

***Skills:*** visitors learn how to do something and gain the ability to do new things. It includes intellectual skills, information management skills, social skills, communication skills, and physical skills.

***Attitudes and Values***: visitors change or elaborate their feelings, perceptions, and opinions about themselves or attitudes towards other people. The visit might result in increased capacity for tolerance, or more motivation for engagement with the subject matter.

***Enjoyment, Inspiration, and Creativity***: visitors gain something beyond learning, for example enjoyment, or surprise from something they encountered. They may be inspired to create or make innovative thoughts as a result of their visit.

***Action, Behaviour, and Progression:*** visitors resolve to take action on a matter following their museum experience. For example, an exhibition on environmental sustainability might lead visitors to resolve to regulate their energy use, or recycle more. Or after visiting a science exhibition, a young child might resolve to become a scientist. This GLO captures the transformative potential of a museum visit, where a disinterested visitor can become a curious and involved learner.

### 2.5.3 The Attention-Value Model of Visitor Engagement

Bitgood's (2010) attention-value model of visitor engagement offers a lens through which to examine visitor engagement with the space of the museum. He defines visitor attention as:

> "a group of psychological and physiological processes that involve a continuum of three stages (capture, focus, and engage) with each stage sensitive to a unique combination of independent variables. Actions that result from these processes are motivated by the interaction of personal factors (person value, interest, past experiences, etc.), psychological-physiological factors (perceptual, cognitive, affective, decision making, fatigue), and environmental factors (social influence, architectural and exhibit design). The indicators (dependent variables) of attention include approaching an object, stopping, viewing time, reading, talking with others about, thinking about, tests of learning and memory, rating scales, and the like. A different set of responses (indicators) occur at each stage."
>
> (Bitgood, 2010: p.2)

This meaningful definition provides a vivid picture of the construction of visitor attention. It identifies three sets of factors that influence visitor engagement: *personal, psychological-physiological, and environmental* factors. These factors work together in the processes of focusing one's attention – a continuous process that moves from *capture* to *focus* and ends with *engagement*. This is an inter-connected continuous process, rather than a set of distinct phenomena. The reactions and behaviours of the visitor in each stage are dependent upon a unique combination of variables that drive visitors into processes and responses with the indicator of attention.

**<u>The Capture Stage</u>**

This is the initial stage of attention. As soon as this stage begins, attention is unfocused as the visitors are in the early process of exploring the museum environment while surrounded by stimulus inputs. This stage can happen during orientation within the museum space and scanning of the exhibition floor. The orientation process is an automatic response to the powerful stimuli in the environment of the museum, such as a loud noise or colourful lighting. However, Bitgood (2010) warns that too much stimulus can result in disruption, because it can distract from visitor concentration in other parts of the exhibition. Scanning in search of something to attend to is another process related to capturing attention. It can be sequential (serial), i.e. examining one object after another until they find something of interest; or simultaneous (parallel), i.e. looking for something prominent in the environment to attend to. The actions involved during the search process of the capture stage include looking at the exhibit elements, feeling, touching the exhibit, and stopping to view the exhibit. The response indicators for the stage of capture include scanning or glancing, looking at or hearing, approaching, and stopping at the exhibit element.

Considered in the variables that influence the capture of attention are five exhibit characteristics: stimulus salience or distinctiveness, visual and physical access, organisation or layout of the exhibit elements, distractions, and perceived value. The stimulus salience or distinctiveness refers to distinctive objects or environments that are prominent and automatically capture visitor's attention as part of the orienting reflex, such as loud or strange noise and sudden movement. The visual and physical access includes sight and landmark. The organisation and layout of the exhibit elements are denoted by a conceptual layout that is created by designers. Appropriate exhibition design provides an increased likelihood of capturing visitor attention. Bitgood (2010) suggests that exhibition design is most effective when it encourages sequential rather than simultaneous searching. Finally, distraction refers to activities that make visitors reduce their level of concentration or attention.

**The Focus Stage**

Focus follows the capturing of attention when the learner's focus continuous attention is narrowed down to a single object or element. The focus stage requires paying attention to a specific thing at a time and disregarding the surrounding objects. This stage involves peripheral processing and can easily be distracted by another powerful stimulus. The visitor actions or behaviour at this stage last no more than a few seconds and include reading the information quickly or simple manipulation of exhibit elements without processing it. This means that visitors will only be introduced to the objects. It does not involve sustained use. The focus stage precedes the stage of engagement.

**The Engagement Stage**

This level involves deep processing of the exhibit content. It requires concentration and an effort to engage with the exhibit content for longer than a few seconds. This stage can also include sustained physical interaction with the exhibit elements. The outcomes of engagement include meaning making and includes a series of cognitive processes, such as critical thinking related to the exhibit content, further inquiry, or scientific reasoning. The outcome can be an emotional response, such as aesthetic appreciation, or adverse reaction to certain information.

Behavioural indicators of engagement include critical discussion with friends related to the content of the exhibit, reading the explanations in the text panels, analysis or synthesis of exhibit content, talking about feelings related to the exhibit content, and sharing their opinions with members in their groups.

Engagement can be influenced by various factors. These include the visit agenda, the visitor's physical/mental state, or fatigue following a long tour. The engagement stage occurs after attention has been focused and the visitor makes a conscious assessment of value, whether the object is worthy of engagement. This requires deep mental processing, sustained for long periods. Engagement is a collection of processes that can help us to identify outcomes that are recognised as learning, attitude change, emotions and feelings.

Table 2.1 shows conclusion of each stage of attention from Bitgood's visitor Attention-Value Model.

Table 2.1 The Attention-Value Model of Visitor Attention (Bitgood, 2010: p.28)

| Stage of Attention | Response Indicators | Explanatory presses/Mechanisms | Factors that influence the experience |
|---|---|---|---|
| Capture | Look at<br>Feel<br>Touch<br>Approach<br>Stop | Orienting reflex<br>Searching (sequential or simultaneous)<br>Decision making<br>Physical/mental states | Salience<br>Visual-physical access or Proximity<br>Organisation/layout of elements<br>Perceived value<br>Distraction |
| Focus | View element for a few seconds<br>Touch object briefly | Narrowing of attention from a broad frame of reference to a single object | Isolation<br>Perceive value<br>Organisation layout<br>Focusing devices<br>Contrast with background<br>Distraction |
| Engage | Read text labels<br>Discuss content<br>Report feeling | A number of intellectual, perceptual, and affective, processes (learning, flow, inquiry, immersion, etc.) | Perceive value<br>Message characteristics<br>Action tendencies<br>Physical/mental states<br>Qualities of the exhibit elements<br>Distraction |

## 2.6 Conclusion

This chapter has discussed three theories of learning relevant to this research project: *Constructivist Learning Theory*, *Discovery Learning Theory* and *Sociocultural Learning Theory*. Within the museum context, these three theories define essential principles that help shed light on interpretation strategies used for enhancing visitor knowledge and learning at the exhibition site.

This chapter has also reviewed existing literature on family learning in the Science Museum, grouped under six main themes: '*Family as a context for learning'*, which examined scholarship that highlights the importance of the family group as a context for learning; '*Families in the museum'*, which discussed the definition of family groups and gave an overview of the family experience in the museum; '*Family learning in the museum*', which looked more closely at family learning; '*Supporting family learning in the museum'*, which attempted to interpret guidance offered by previous literatures to effectively enhance family learning in the museum.

Next, this chapter gave an overview of the established potential of mobile technology to enhance visitor learning in the museum. The shortage of research on family groups and how mobile technology can support their visit and enhance their learning experience motivates the main research question in this thesis, which seeks to identify the learning impacts of mobile technology for family groups in the science museum.

The final section of this chapter, '*Identifying learning in the museum'*, explored models and frameworks of museum learning and engagement that can guide the identification of such impacts. These included the *Contextual Model of Learning*, the *Generic Learning Outcomes* framework, and *the Attention-Value Model of Visitor Engagement*.

Chapter 3 pulls these literatures together into a research methodology focused on exploring the potential of mobile technology to support family experiences in the science museum.

# CHAPTER 3 : RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter presents the research methodology of the thesis, which included (a) a preliminary study that focused on the analysis of the needs of family visitors, (b) the design and development of a mobile application for families to meet these needs, and (c) an evaluation of the mobile application with families in the museum.

The main aim of this research was to explore and understand the impacts on family learning of the integration of mobile technology within the family visit to science museums. Recent years have seen a wealth of studies in the use of mobile technologies to support museum visits (see for example Falk & Dierking, 2008; Hsi & Fait, 2005; Laurillard, 2007; O'Hara *et al.*, 2007; Pachler, Bachmair & Cook, 2009; Scanlon, Jones & Waycott, 2005; Sharples *et al.*, 2008; Tallon, 2008; Vavoula & Sharples, 2009; Vavoula *et al.*, 2005), but little research in the area of mobile learning has focused specifically on family groups. As discussed in Chapter 2, the family is a museum visitor group with particular characteristics, including a shared history of interactions that underlie both the visit agenda and the learning frameworks of individual family members.

One of the main characteristic of mobile technology is that it is personal (Sharples, Corlett & Westmancott, 2002). Use of mobile technology within the family group presents an interesting case, as families value the 'shared-ness' of their visit. It is therefore important to understand how the introduction of technology that is primarily personal might impact an experience that is valued for its intra-group interactions. As discussed in Chapter 2, families in the science museum in particular want experiences that are hands-on, allow multiple users and multiple entry points, facilitate family interactions, and enable parents to facilitate the children's learning without overlooking their own learning needs (see for example - Ash, 2003; Blud, 1990; Borun, Cleghom & Garfield, 1995; Borun, Chambers & Cleghorn, 1996; Borun *et al.*, 1997; Diamond, 1986; Dierking *et al.*, 2001; Ellenbogen, Luke & Dierking, 2007, 2004, Falk & Dierking, 1992, 2000, 2008; Hilke, 1989; Hooper-Greenhill & Moussouri, 1999; McManus, 1994; O'Hara *et al.*, 2007).

This study thus focused on the impact of mobile technology on the family visit to the science museum. The word *impact* is used as a general term that captures changes in the ways that families engage with and learn from the museum visit-changes that result from the integration of mobile technologies within the family experience. Through a case study of developing and evaluating mobile tools for families in a science museum, this research examines what these impacts are and why they occur.

<u>The main research question addressed in this thesis therefore is:</u>

1. What are the impacts of mobile learning tools on family learning in the science museum?
   1.1. How can we identify and assess these impacts?
   1.2. How can we design for these impacts?

To answer the main research question, this thesis takes a design-based approach: focusing on a case study museum, a learning needs analysis of family visitors feeds into the design and development of a mobile app for families; a comprehensive evaluation of the app follows, through an experimental design (Gray, 2004) in the naturalistic setting of the case study museum.

Question 1.1 relates to the experimental design and is a methodological one: given the difficulties in capturing and measuring learning in the museum discussed earlier in this thesis, how can we identify the impacts on family learning of mobile learning tools that are aimed to support family visits to science museums? One possible answer to this question lies in this chapter and has the form of a methodology for identifying and capturing impacts on family learning. The answer to question 1.2 relies on a reflection upon the answers to the main question that translates findings on impacts into guidance for design that reinforces desirable and limits undesirable impacts on family learning.

Figure 3.1 gives an overview of the framework of this research. The box labelled as 'Process' shows the three stages of the research. Within it, 'Requirements' represents the preliminary study of family learning needs analysis, 'Design' represents the process of implementing the design framework that emerged from 'Requirements' into a mobile app for family visitors, and 'Evaluation' represents the final stage of identifying and capturing the impacts of the app on family learning in the science museum. The learning theories of discovery learning, constructivism and sociocultural learning informed the design by providing the researcher with an understanding of the processes of learning and how best to support them. Finally, the three analytical models of museum learning (contextual model of learning, generic learning outcomes, and attention-value model of engagement) gave structure to the collection and analysis of data related to learning impacts.

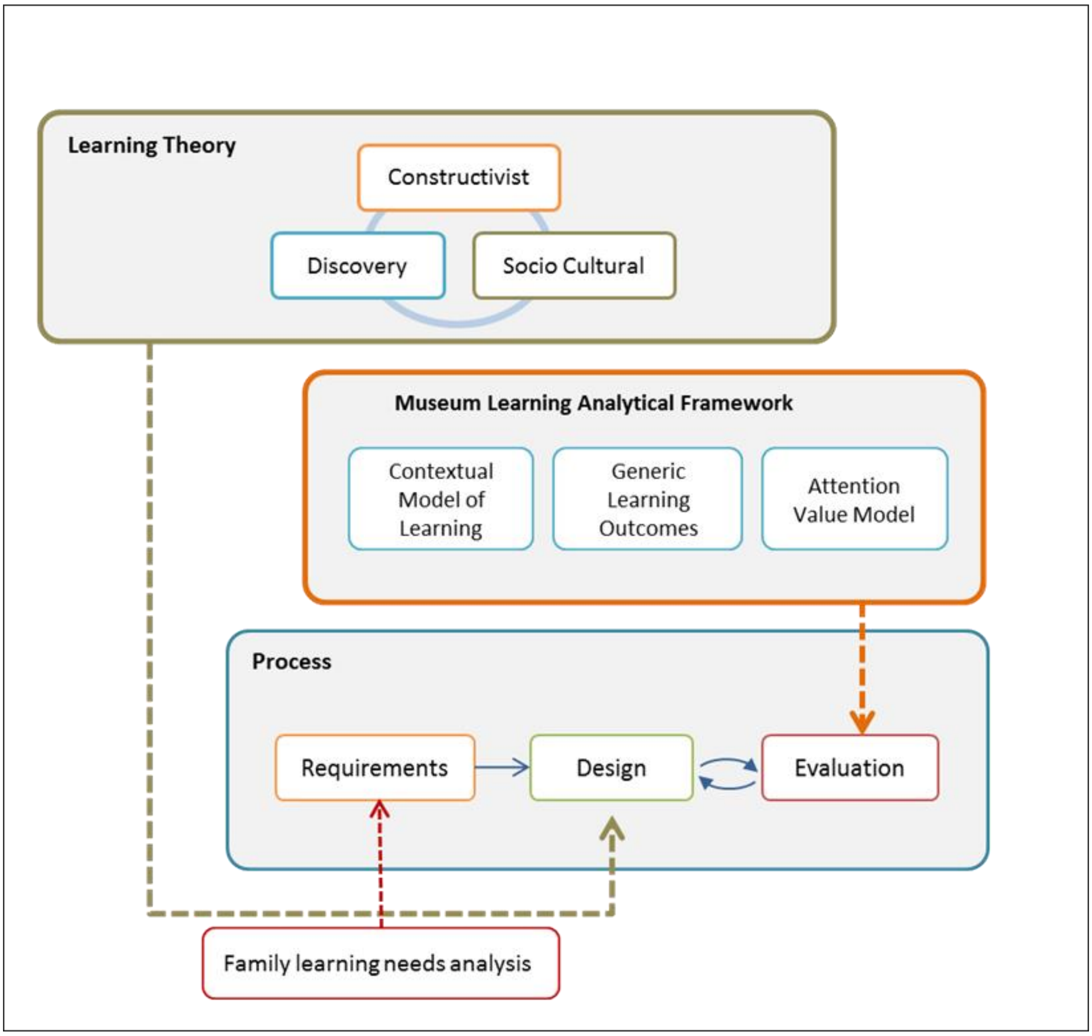



*Figure 3.1 Framework of the research.*

The following sections give background on the case study museum and discuss in more detail the research activities that contribute to answering the research questions.

## 3.2 Case study setting: National Science Museum, Thailand (NSM)

The researcher has worked as a science communicator at the National Science Museum, Thailand, since 1998. The Museum has been supportive of this research from the beginning, allowing the researcher to take time out of full time employment to undertake doctoral study. My knowledge of the museum and experience of how it is used by visitors provided a solid basis both for coordinating the development of the mobile app, and organising the fieldwork. My original intention was to take into account in my study any particularities of the Thai informal science learning context, and understand how these particularities might impact on the family experience. However, the preliminary study that focused on family needs analysis did not reveal any discrepancies between the needs of Thai family audiences and the literature on family science learning in Western museums. It was therefore concluded that the Thai context does not present an additional parameter to be considered.

The National Science Museum (NSM) has become the largest science museum in Thailand since its launch in 2000 by the Government through the Ministry of Science, Technology and Environment. The project was initiated in honour of Her Majesty the Queen on the occasion of the 5th cycle birthday anniversary, on the 12th of August, 1992, in appreciation for her efforts in introducing science and technology to local Thai communities with the purpose of developing practical skills for local people's employability. The Queen's initiative aims to improve local people's practical skills and increase employability opportunities. This in turn leads to the improvement of living standards, especially for poor people in rural areas.

The NSM was founded as the organisation that takes responsibility to organise, manage, and develop a Science Museum that delivers to the public the fundamentals of science and technology and their applications. The museum sits alongside a series of other science related museums, comprising the Natural History Museum, which offers knowledge about natural history including the origin of life, evolution of life, biodiversity, to the extinction of creatures; the Information Technology Museum, which provides the visitors with an understanding of the basic principles of communication, computers, networks, and information technology; the Rama 9 Museum, which introduces His Majesty the King Bhumipol's systematic problem-solving approach and self-sufficiency principle; and the NSM Science Square, which is set up at Bangkok's city centre and aims to provide a place where families and young people can spend and enjoy time with the world of everyday science and cutting edge technology through science exhibitions and science activities. All these museums are located in the Technopolis complex of Klong Luang area close to canal number five (Klong 5) in the Pathum Thani province, except for the NSM Science Square which is located in the heart of Bangkok, at the Chamchuree Square Building (as shown in Figure 3.2).

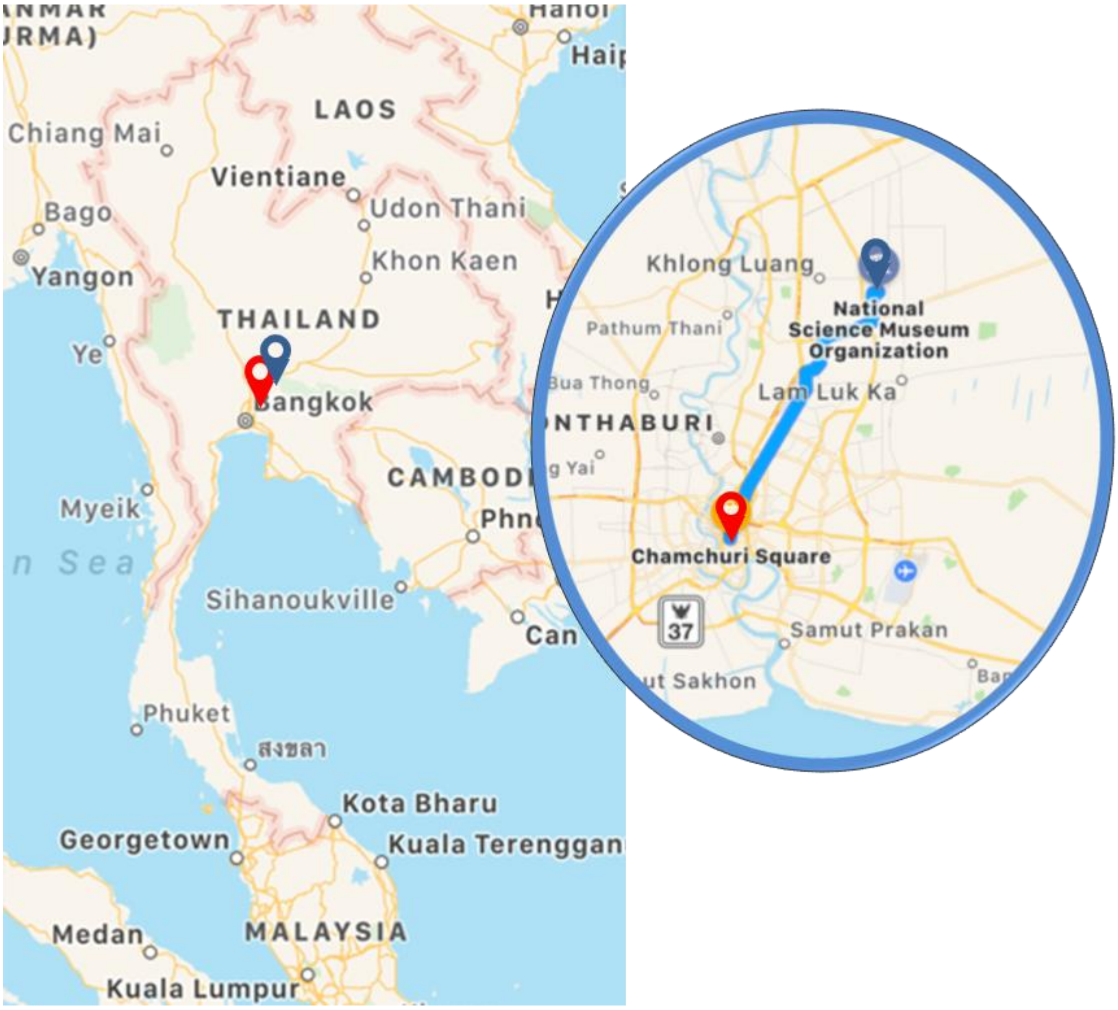



*Figure 3.2 Map showing the locations of the National Science Museum and the Chamchuli Square.*

The NSM aims to be a centre of excellence in learning-centre development, management and utilisation, and to better promote public awareness of science. Its mission is to accumulate local wisdom, to communicate science, and to promote science learning in society. In order to achieve this mission as a non-profit organisation, the NSM attempts to promote science to the public through many channels, including museum exhibitions, educational and public programs, outreach programs, science media, professional development programmes, and research studies on topics of science communication and biodiversity.

The production of the iconic building shown in Figure 3.3 that houses the Science Museum was the first step of the entire project, and has become an impressive destination for at least 750,000 visitors each year. It aims to provide experiences of fundamental scientific knowledge through hands on and interactive exhibits. The building has six storeys with an exhibition and activity area of approximately 10,000 sq.m. This area displays more than 250 hands-on exhibits and models about science and technology in everyday life, which aim to introduce visitors to fun science learning experiences and to encourage a lifelong learning mind-set within every walk of life. The scientific knowledge and science-related activities at this science museum are aligned with the mission of the organisation and serve the purpose of familiarising the public with science and technology in everyday life, and encouraging the understanding of the relationships between science and society, including Thai local wisdom.

*Figure 3.3 The Science Museum building and the fountain bay (National Science Museum, Thailand, 2013c).*

The exhibitions that are displayed in the Science Museum are divided into six main themes, each occupying one building storey. The main entrance on the ground floor (referred to as 'first floor' in Thailand) leads to a reception and box office area, which provides information and ticketing services for the entire museum and all the available activities, as well as a souvenir shop. Information displays on this floor tell stories about the great scientists of the world and their discoveries that changed the world, in order to inspire visitors with the value of scientific discovery. The ground floor also houses temporary exhibitions, which are typically set up and displayed for three to six months.

The first floor (second floor in Thailand) displays information panels and models related to the history and development of science and technology in the world. This floor displays one of the museum (Figure 3.5). The gate on this floor connects to a stunning dancing fountain outside the building, which works synchronously with music at evening time (as can be seen in Figure 3.4).

The second floor (third floor in Thailand) provides interactive and hands-on exhibits on the topic of Basic Science and Energy. On this floor, visitors get to experience interactive exhibits that connect everyday life activities with fundamental concepts of science, such as the properties of sound, light, heat, wave, electricity, force and motion, gravitational forces, friction, magnetism, matter and molecules, energy, and the basics of chemistry. Visitors can engage with hands-on exhibits that allow them to discover and understand scientific phenomena by doing experiments with the exhibits themselves (Figure 3.6).

On the third floor (fourth in Thailand), the main theme is *science and technology of Thailand*. This floor provides information about geography, location, climate and weather, geology, ecology, architecture, building, farming - all the scientific information that relate to the science and technology of Thailand. Visitors can explore models and interactive multimedia exhibits, and gain information about how and where science and technology are utilised in Thai society such as how Thai buildings and the construction industry are supported by science and technology knowledge.

The fourth floor (fifth in Thailand) exhibits how science and technology are connected to the daily lives of people around the world, under the theme *Science and Technology in Daily Lives*. Visitors can discover what science and technology has been used to improve the quality of life and how, on aspects of life ranging from public health to transportation. Visitors are given a flavour of how and why we employ different scientific concepts and different technologies in each situation, in order to overcome specific obstacles successfully.

On the fifth floor (sixth in Thailand), which is the topmost floor of the building, the main theme is *Traditional Thai Technology*. On this floor, visitors can explore the traditional technologies that were used by ancient Thai people centuries ago, and some of which are still in use, such as wood carving, pottery, metallurgy, wicker work, and textile technology. The concept for this exhibition is to connect traditional Thai technology with scientific knowledge and to honour Her Majesty the Queen for her efforts in promoting science and technology into Thai culture and traditional Thai technology.

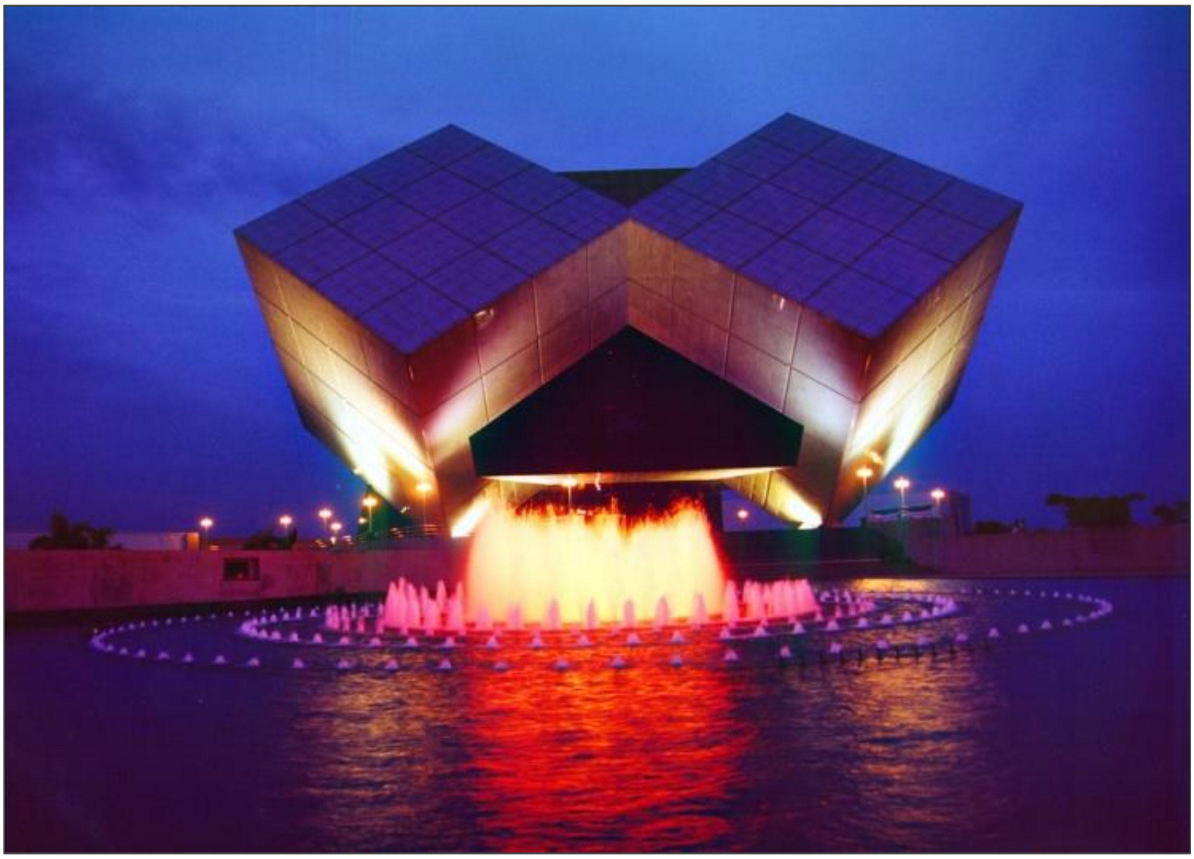


*Figure 3.4 Science Museum at Night (National Science Museum, Thailand, 2013d): the dancing fountain outside the building of the Science Museum.*

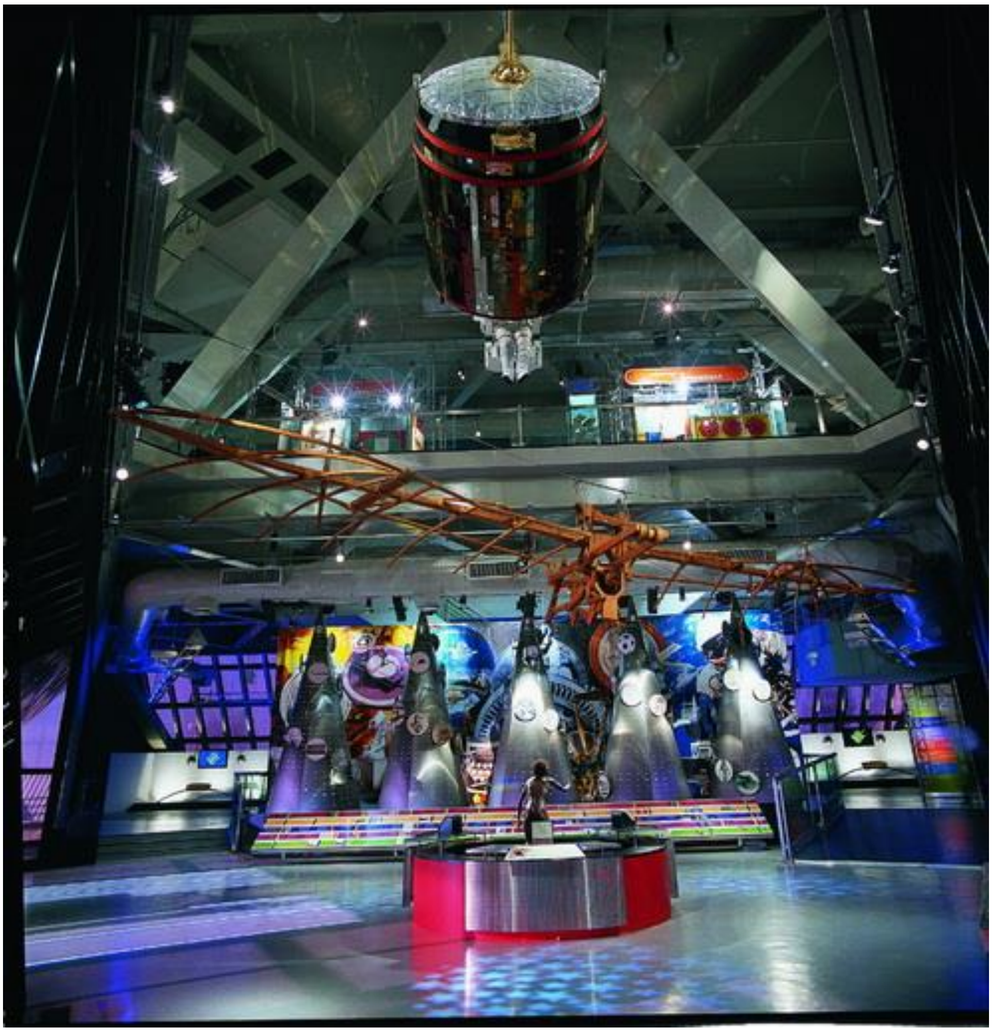


*Figure 3.5 Picture display exhibition on the first floor (National Science Museum, Thailand, 2013e).*

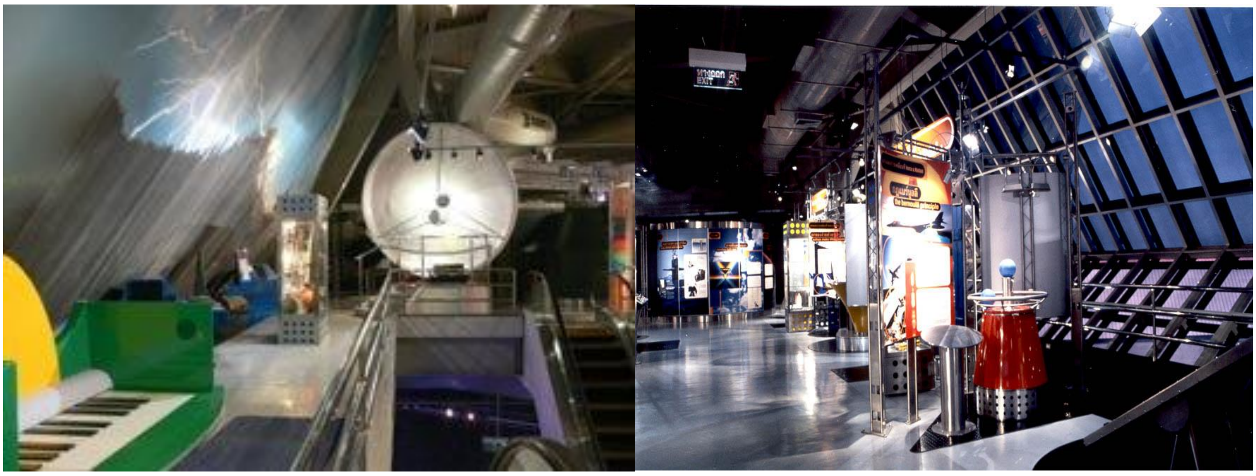


*Figure 3.6 Picture displays exhibition on the second floor (National Science Museum, Thailand, 2013a).*

To support its mission, apart from the exhibitions the NSM offers many kinds of educational activities for school students at all educational levels, as well as public programs related to science targeting families, children, and adults. Some of these programs are offered in English on request. One example of education and public programs is the forty- five minute Egg Show, which demonstrates the physical characteristics of material and their applications, such as the arc structure of a bridge. It uses eggs, which are among the most popular foods in Thailand, as a tool to explain to audiences the scientific knowledge. In a similar format, the Bubble show describes the scientific concepts related to surface tension, shapes, and the volume of matter with the use of soap bubbles. A third example of the NSM's public programming is the Science Cultural Camp, which is one of the most famous education programs that encourage children to live, learn, and discover science together. The young science campers can spend time to develop their social skills and systematic thinking skills at the same time. A fourth example is the Science Laboratory, which is a public education program that introduces scientific skills to school groups and family groups through science experiment sessions in real laboratory rooms. Finally, the Science Caravan is one of NSM's most popular public programs of activities. This program takes NSM's travelling exhibitions and activities to schools and public events across the country and neighbouring countries such as Laos. The NSM, as a non-profit organisation, employs this program as a tool to promote science too hard to reach publics, and encourage people who cannot afford the cost of travelling to the main museum to gain experience and become familiar with science and technology as much as possible.

In order to achieve its mission, every year the NSM designs and launches new public education programs, science competitions, professional development programs (related to science communication, science activities and natural history related programs), science popularisation programs, and research on science communication and biodiversity. Moreover, the NSM offers to its publics science information and features related to science and technology through various media including journals, magazines, science radio programs, television programs, websites, e-exhibitions, leaflets, pamphlets, and books in order to provide more opportunities for the public to become familiar with science as much as possible.

The NSM is an informal science learning organisation that takes its mission seriously, looking for innovative, enjoyable ways to engage its audiences with science and to extend its reach to harder-to-reach audiences. The museum, which had not engaged in visitor studies before, welcomed this research which aimed to shed light to its family offer and facilitated all three stages of the research. These stages are discussed below.

## 3.3 Preliminary Study: Family learning needs and desired support

The preliminary study in this research was designed to focus on understanding how family audiences currently experience the NSM, in particular, 1) what are their views of the museum's current provision, and 2) what additional provision could engage more families and lead to deeper engagement with the science museum's exhibitions; both with a view to improving learning and understanding of scientific content for family groups.

This part of the research started with a series of literature reviews on related areas including informal science learning, family learning in the museum, mobile learning, and family science learning, which were presented in Chapter 2. Under a socio-cultural learning lens, the literature reviews led to the construction of a theoretical framework of family learning in science museums, drawing on constructivist and socio-cultural accounts of learning as well as discovery learning. The theoretical framework has been expanded through a qualitative survey with museum staff and family audiences in the National Science Museum, Thailand.

A qualitative approach to data collection was employed in this preliminary research, which included interviews with three groups of stakeholders: 1) family groups, who visited the NSM, 2) members of staff from the NSM, and 3) mobile media developers who had experience of developing mobile applications for other museum settings and users. The interviews were audio-recorded and the researcher kept additional notes during the interviews. In this research, a family group comprises at least one parent and at least one child between six and twelve years old. We use the qualifier 'parent' to denote the responsible adult(s) in mixed adults-children groups. This means that a family group may include children visiting with parents, carers, grandparents, family friends, etc. The NSM staffs that were interviewed were recruited among staff who have been working for the museum for more than 10 years and have extensive experiences of the museum's public education programs and exhibition development programs. The mobile solution developers were selected based on prior experience in the design and development of mobile applications for museums in Thailand.

The ethical protocols adopted by this project were approved by the University of Leicester's College of Social Science, Arts and Humanities Research Ethics Committee prior to the commencement of the research activities. Ethical approval included permission to interview parents and children in the museum environment, and permission to interview museum staff and mobile media developers. Consent forms from participants in this study were collected and are deposited with the School of Museum Studies, where they will be kept securely for six years after the end of this research.

Due to limitations imposed by the distance between Thailand and the UK where the researcher was based, the interviews with family groups in the preliminary phase were carried out by a research assistant in Thailand, while the interviews with the NSM staff and the mobile media developers were carried out over the telephone. After the interviews, the data was transcribed and analysed using the Grounded Theory method (Glaser & Strauss, 1999) to generate themes around family needs. The data and information gathering from the preliminary field work was subsequently developed into a design framework that guided the development of a mobile solution (a web-based mobile app) that fulfils the learning needs and desired support for family audiences. Chapter 4 of the thesis presents the findings from this preliminary study, including the design framework, while Chapter 5 presents the development of the mobile app that was based on this design framework.

## 3.4 The development of the mobile app

The development of the mobile application in this research project has been partially supported and funded by the National Science Museum, Thailand, and Thailand's National Electronics and Computer Technology Center (NECTEC). In the second phase of this research, a mobile app for smartphones was developed as a tool for enhancing family visitors' science learning at the National Science Museum, Thailand. As the NSM is a state enterprise which is supported by the Government's Ministry of Science and

Technology, the development of any tool that related to the mission of the NSM needs permission from the organisation's committee. After permission was secured (following a process that lasted one month), the project started and the development team was formed. The team comprised members of the museum's IT unit who are in charge of the technical support required for operating the application, such as to link the database to the domain server and the system; members of the museum's Science Communication unit who are involved in preparing suitable exhibition content as well as the design of communication techniques appropriate for use in this tool. The development of software for this project attracted the interest and support of the National Electronics and Computer Technology Canter (NECTEC), which took responsibility to develop the application from the content, video materials and designed communication structure provided by the communication unit.

After the project was embraced and approved by the museum and a budget allocated to it, I liaised with the project members to ensure that the family needs and requirements from the preliminary study fed into the development of the application. Therefore I wrote the specifications and oversaw the installation of Wi-Fi in the museum for the IT unit, who set up the network system in order to provide adequate data throughput for the mobile application on the NSM domain. These processes took almost 9 weeks to be completed. It was important for the mobile application in this study to work over the museum's Wi-Fi in order to enhance the speed of the application connection to the database via the museum's server, and to ensure lower costs for users. This means that the family visitors who connect to the Wi-Fi do not need to pay for the service and also can easily control the functionality of the application that includes text, pictures, audio, and video based content about the exhibits. The system comprises a front end part, which is the one that the users interface with; and a back end, which is the part of the system that museum staff can use to modify the content and design of the application.

The content, structure and features of the mobile application have been designed based on the requirements that were collected through the preliminary study. The application was created for both iOS and Android operating systems. The mobile app is discussed in detail in Chapter 5 of this thesis.

## 3.5 Summative Evaluation: Evaluating Mobile Family Learning in Science Museum

The last phase of this research was designed to answer the main research question, namely to identify the impacts of the mobile app on family learning in the science museum. Through an experimental design (Gray, 2004), this part comprised in-situ studies of the mobile app that enabled capturing how families adopt and adapt to these technologies for their visit. Moreover, interactions of a control group were compared against interactions of an experimental group of families. Families in the control group visited the museum without the app, whereas families in the experimental group used the mobile app during their museum visit. A third group was included in the study: a usability group of families who used the app but were asked only questions related to the usability of the app, without any questions about other aspects of their visit. This was to avoid overloading families in the experimental group with a very lengthy questionnaire. Data about the three groups were collected through:

1) Pre and post-visit interviews with family groups in the museum. Data was recorded through note-taking and audio recording. The questions used in the pre and post visit interviews can be seen in Appendix 6. Both the control and the experimental groups took part in this activity.

2) Post-visit usability questionnaires. The Simple Usability Scale (Brooke, 1996) was used to devise a questionnaire that measured the usability of the app. Usability gives a measure of how useful, effective and satisfying to use a product is. Vavoula & Sharples (2009) argue that usability issues can escalate to the learning experience level and impact a learning experience even when the educational/instructional design that makes use of the technology is robust. The development of the app in this research involved a number of iterations (see chapters 4 and 5) to ensure an acceptable design. The usability evaluation in this final stage of the research serves to evidence that, indeed, the app is acceptable in terms of usability. In doing so we can be confident that the impacts on the family experience (which are captured by other activities in this stage of the research) have not been affected by usability issues. The Simple Usability Scale comprises 10 Likert Scale questions that can be adapted to suit the particular application that

is tested. It is one of the most efficient tried and tested tools that can provide statistically valid data and reasonable feedback within a short period of time, with very little administration overhead. This questionnaire was completed by the Usability group. The SUS questionnaire used in this study can be seen in Appendix 5.

3) Modified personal meaning mapping. Unlike the original Personal Meaning Mapping method (Falk, Moussouri & Coulson, 1998) which requires participants to draw meaning maps of their understanding of the concepts, phenomena and ideas explored in the exhibition before and after their visit, this research sought to capture these through exhibit-specific interview questions for the whole family, while also enabling the child(ren) in the family group to draw pictures or write text related to what they found interesting about the exhibits. This was necessary, as the children in the family groups were from as young as three years old up to late adolescence, therefore meaning maps were not appropriate for all ages. Like with the Personal Meaning Mapping method, however, the family interviews and the children's drawings took place both before and after the end of the family visit, enabling a comparison of the families' knowledge and understanding before and after visiting the exhibits. Drawing was an optional activity for children, allowing them to contribute to family responses to the interview questions instead.

4) Video recording-based observation of family groups in the museum galleries. The museum's security cameras were used at two of the highlight exhibits to collect video data (image only, not sound) of families' interactions at the exhibits. These recordings substituted direct observations, which would have been more obtrusive for the families. Not all the families who were video-recorded had participated in the interviews / drawing activities, therefore this dataset was analysed separately. The video recording-based observation aimed to capture and record behaviours of family visitors who visit the science museum; how they interact with each other, museum staff, and media in exhibitions, as well as the length and quality of their experiences.


*Figure 3.7 The footage frame of the family in control group at the Plasma ball exhibit.*


*Figure 3.8 The footage frame of the family in experimental group at the Plasma ball exhibit.*

**Participants**

Family participants were recruited from those visiting the museum on designated data collection dates. The ethical protocols adopted by this project were approved by the College of Social Science, Arts and Humanities Research Ethics Committee prior to the commencement of the research activities. Ethical approval included permission to speak with the parents and children in the family groups in the museum environment and permission to video record families at the exhibits. Consent forms from participants in the questionnaires were collected and are deposited with the School of Museum Studies.

Visiting families were not asked for explicit consent to be video-recorded. Instead, signs were placed at the admission desk of the museum, as well as at the observed exhibits, informing visitors that some areas of the exhibit were observed by video. Visitors who did not want to be filmed were advised to ask to talk to a member of staff, who would then turn the camera off. No families asked not to be recorded.

Families were approached at the entrance of the museum and asked whether they consent to take part in the study. Families were selected randomly, as the researcher approached the first family to enter the museum after the previous participating family had finished their post visit questionnaire. When a family refused to participate, the next family to enter the museum was approached.

The questionnaire-based interview in this research was designed to collect data from all three participant groups, i.e. the control group, the experimental group, and the usability group.

**The role of the analytical models of museum learning in the summative evaluation**

The design of the research questions and activities in the summative evaluation are based on the three analytical models of museum learning discussed in Chapter 2: the Contextual Model of Learning, the Generic Learning Outcomes, and the Attention-Value Model of Engagement.

The Contextual Model of Learning is a useful tool in the evaluation of family group visitors' museum experiences. Falk suggests that each museum visitor has their own particular personal agenda and motivation (Falk, Moussouri & Coulson, 1998; Falk & Dierking, 2002, 2013). Family groups, however, visit with a shared agenda and purposes that may accommodate individual differences between family members, but are at the same time strong enough to hold the family group together during their visit. The summative evaluation in this research therefore takes the family as the unit of analysis, focusing on shared agendas and objectives, within-family interactions and behaviours, and commonly developed science knowledge and understanding. Thus, families were interviewed and observed as a group rather than individually, and measures of knowledge and understanding were developed at the family rather than the individual level. This research therefore focused on the interplay between the family context and the museum environment and how this interplay shaped family learning.

The Generic Learning Outcomes (GLOs) framework gave us an impetus to look for more than congitive gains in how the visit impacted families, thus also looking at skills, changes in attitudes and values, evidence of enjoyment, inspiration and creativity, and evidence of activity, behaviour and progression. The richness of the GLOs framework ensured that the research placed due emphasis both on the learning of science and on the understanding of the value of science in society.

Finaly, the attention-value model of visitor engagement guided the analysis of the video-based observation data, providing a useful guide to scrutinising family behaviours at the exhibits and what underlying learning processes these behaviours might indicate.

Further details of data collection procedures and analysis of data as well as the findings from these activities are discussed extensively in Chapter 6.

# CHAPTER 4 : FAMILY LEARNING NEEDS IN THE SCIENCE MUSEUM

## 4.1 Introduction

This chapter introduces the family learning needs analysis that was conducted in the first stage of the research. The analysis aims to generate requirements for designing a mobile application tool that will serve the needs and requests of family visitors in regards to their science learning experiences in the National Science Museum, Thailand (NSM). Data collection was conducted in 2012 through interviews with family visitors, NSM staff, and the museum's mobile solution developers. Following a Grounded Theory approach (Glaser & Strauss, 1999), data was coded to generate themes under the generic areas of 'needs' (i.e. essential family learning support that is currently either lacking or not sufficiently available in the museum) and 'requests' (i.e. a family learning support wish-list). Findings from the analysis were subsequently matched against the conceptual framework presented in Chapter 2 and guided the design of the mobile application which will be presented in Chapter 5.

## 4.2 Methods, techniques, participants, procedures

The family learning needs analysis was conducted in September 2012, following the granting of ethical approval for this research. This first phase of the research was conducted by interviewing family groups (parent(s) and child(ren)), National Science Museum (NSM) staff, and mobile solution developers. Interviews were audio recorded and notes taken by hand. The collected data were analysed according to Grounded Theory methodology (Glaser & Strauss, 1999).

## 4.3 The Participants

Three groups of stakeholder were interviewed in this part of the research:

1. Family visitors: groups comprising at least one adult and one or more children aged six to twelve were interviewed as the main stakeholder group for this research, which seeks to support family learning in the Science Museum.
2. Science museum staff: experienced (over 10 years of service) exhibition developers, educators and gallery facilitators in the Science Museum were also interviewed as a stakeholder group who are responsible for the provision of learning support.
3. Mobile solution developer: the Science Museum would have to outsource the development of the mobile family learning support tools; the mobile solution developer represented a third stakeholder, who would be able to provide input on technical limitations and constraints as well as on technical capabilities and possibilities for supporting family learning in the museum.

Family participants were recruited from those visiting the museum on the date of data collection. At the entrance of the museum family groups were asked whether they consented to take part in the research. The first family to enter the museum after the previous interview had been completed was approached. If a family did not consent to participate, the next family to enter the museum was approached. A total of 9 families were interviewed in September 2012.

At First, the fieldwork was initially planned to start in December 2011. However, there were problems with the number of family visitors during that month, which had declined significantly because of the severe flooding in Thailand from October to December that year. At that time, the national science museum had to close as its surrounding area was directly affected by the flooding. The field work plan had to change accordingly. As I was not able to be physically in Thailand when the museum re-opened and family visitor numbers returned to normal levels, I asked a science educator at the museum to do the family interviews on my behalf. I then went on to conduct the staff interviews myself, by phone rather than face-to-face.

Interviews with six of the science museum staffs and 2 of the mobile solution developers were conducted by telephone, after they had consented to participate in this interview.

## 4.4 Ethical considerations.

Before the start of the data collection, I had contacted the museum director and had been granted permission for this study. In terms of ethical considerations, there were three main issues in this research:

1) Interviews of young children in family groups: although vulnerable groups (i.e. children) were involved in this research, the setting of their participation ensured that risks were reduced. More specifically, the children participated only if all the accompanying adults and the children themselves gave informed consent. Upon approaching a family, the researcher offered a full verbal explanation of the research project, the family's role in the research, what their participation would involve, how the data would be used, and how their anonymity and confidentiality would be safeguarded. The researcher was careful to explain these in plain language, so that both adults and children could understand what they were asked to consent to. The researcher then gave a research information sheet to the adult(s) and another to the child (ren) (each version written in age-appropriate language) that explained the project as above. The family were given time to read through the information sheets. All family members were then given a chance to ask questions. Once all questions were answered, family members were asked whether they consent to participate. If they did not, the family was thanked and another family was approached. If they did, all family members were asked to sign a consent form. The interview with the family followed, taking place in a public area of the museum. Although there is no equivalent of a Disclosure and Barring Service in Thailand, any contact with children happened in the presence of their responsible adults, in an open and public area of the museum.

2) A member of staff of the National Science Museum conducted the family interviews on behalf of the investigator. Prior to the interviews this member of staff was fully briefed about the procedures described above (including issues of anonymity and data protection) as well as about the University of Leicester's ethics code of conduct. An advantage to having a member of museum staff do the interviews was that, in addition, they made sure that the museum's ethics code was also adhered to during the interviews. After the interview, the recorded data was digitized by the museum staff member and sent to the investigator via email, through an encrypted document.

3) Interviews were conducted with non-English speakers in their native language (Thai). For this reason, information sheets and consent forms were written in Thai.

4) Access to participants required the co-operation of gate-keepers, namely the management of the National Science Museum in Thailand.

## 4.5 The interview questions

The aims and objectives of this family learning needs analysis, which were to conceptualize the issues currently facing family visitors to the NSM and desirable change to their experience in order to outline a mobile solution to support family learning, guided the development of the interview questions. The interview comprised three main parts.

The first part was designed to explore the current family experience in the NSM, the problems that families face during their visit and how these are met by the institutions. The family groups were asked about the purposes of their visit, what the family does during the visit, their opinions about their experiences, and any problems or obstacles to their science learning that they found in the gallery. Science staff were asked about their opinions about the purposes of family visits and the behaviours of families they have been observing in the galleries as well as the problems they have identified for families.

The second part of the interview question aimed to discover additional desirable impacts, in particular regarding engaging more family audiences, increasing the engagement of family visitors with science museum exhibitions, and improving learning and understanding of scientific content for family audiences. All participants were asked to make suggestions for improvements that could be made to exhibitions or services in the museum and which would help family visitor to engage more and learn more about science from the exhibitions.

The first and second parts of the interview were developed based on the theoretical account of family learning in informal setting presented in Chapter 2, in particular the contextual model of visitor learning in the museum which emphasises the personal, social, and physical contexts of the visit. Personal contexts shape family expectations and the purposes of their visit on the day. The family context defines social interactions between family members and how they behave and interact in relation to the wider social context of the museum gallery. The physical environment of the galleries is where these social interactions are situated, and where the museum offer materialises as a family experiences. How well these three contexts are aligned determines the impacts on the family experience.

The third part of the interview aimed to generate guidelines for the design of mobile technology solutions that are consistent with visitor needs and desires. In this part the participants were encouraged to voice their opinions and ideas about the information and media that they considered would help maximize the benefits of the family learning experience within the museum. Additionally, the interviewees were asked to suggest places in the gallery and types of exhibition that they would like support in exploring. This part of the interview therefore contributed to the design framework for mobile support for families in the NSM.

## 4.6 Findings from the family learning needs survey of staff and visitors at the National Science Museum, Thailand

The data collection from interviews in this part of the research was completed in September 2012. In total, nine family groups were interviewed, as well as six members of the Science Museum staff and two mobile media developers. All of the interviews were noted and recorded and then transcribed into a Word document before the initial coding and analysis were carried out using a Grounded Theory approach. This method allowed the study to frame the key concepts for the design and development of a mobile solution that fulfilled the learning needs and provided the desired support for family audiences in the second phase of design. The key themes that emerged from the data analysis are discussed below.

## 4.7 The current situation and the problems of family audiences in Thailand's Science Museum

**Purpose of the visit**

The results from the interviews with all three groups provided the initial answers in regard to determining the current situation and problems of family visitors to the National Science Museum, Thailand. From the interviews with family visitors, it was found that the main purposes of visiting the museum were to spend leisure time together, have fun, and acquire basic knowledge about science and technology. Most of the families aimed to provide leisure time for their children, and some families stated that the purpose of their visit was to relax and offer their children the opportunity to learn about science through an out-of-school activity. The majority of the family visitors had a positive attitude towards visiting the science museum and agreed that learning science was necessary for their family and for society more generally. The participants appreciated that a science museum is not only a place for leisure, but is also a place where their children can enjoy science learning as an out-of- school activity.

**Family behaviours during the visit**

During their visit, most of the families allowed their children to lead and make choices for the family group's itinerary in the museum. The parents played a supportive role in reading panels and relaying explanations to the children where this was needed and/or desired. All interviewed parents seem to have played the role of facilitator and encouraged their children to engage with the science exhibits; they also discussed the exhibits within the family group during their visit. However, the results showed that during the visit, parents and children had often competing interests as to which route to take and which exhibits to engage with. After a decision on which exhibit to engage with was made, most parents allowed their children to interact with the exhibit on their own, or encouraged them to engage if they were hesitant. While the children engaged with the exhibits, most of the parents tended to provide additional information and sometimes learned along with the children, depending on the availability of information in the gallery and their difficulty level.

**Problems during the visit**

The interview data revealed obstacles to science learning that families encountered in the museum. There were three major problems for family science learning: difficulties in figuring out how to manipulate exhibits, difficulties in understanding the scientific content of the exhibition, and the lack of a facilitator in the gallery when further information or assistance was needed. Most families said that when they arrived at an interactive exhibit, they need to know how to engage with it and how to operate the exhibit. In most cases, families would imitate visitors who were already using it or look for information and help from a staff member. The instructions provided at the exhibit were not always understandable, and families were sometimes unsure whether an exhibit was out-of-order or whether their children were operating it wrongly.

In additionally, parents said that for some exhibits the outcome of the interaction was not possible to interpret and the text panels were unhelpful in this regard. There was therefore a disconnect between the hands-on experience and the available exhibit interpretation. The parents were also aware that some of the content of the text panels was too difficult both for adults and for the children to understand.

Another difficulty encountered by families was in making connections between the scientific concepts, information and theories on display and their real world experience or daily activities. For example, the plasma ball exhibit was very popular and easy to interact with, but there was little explanation as to why this phenomenon matters and what plasma applications they may have encountered in everyday life. Nevertheless, families did enjoy the experience of interacting with these exhibits but appeared to be less concerned with learning the science behind. The predominance of leisure and fun in the family visit agenda can explain this: if a family is there to enjoy the company of each other while pursuing a leisure activity, they will still enjoy a spectacular interactive exhibit such as the Plasma ball, even if the opportunity to learn about the science of Plasma is missed.

Families also identified the shortage of museum staff and facilitators on the exhibition floor. Regarding learning, the families reported that science museum staff or volunteers in the gallery can play an important role in supporting family learning by providing not only general information about the museum and the galleries, such as finding their way and pointed towards museum facilities, but also specific information about the scientific content of the exhibits and how to operate them. Family visitors thought that the lack of available supporting staff in the museum gallery limited their learning opportunities.

Interestingly, science museum staff identified similar problems related to family science learning in the museum, but from a difference perspective. Museum staff also stated that family visitors can find it difficult to understand the operating instructions and the complex scientific content of the exhibits and noted the lack of museum facilitators in the gallery. From their viewpoint, even though instructions are provided for every exhibit, visitors tend to interact with the exhibits without reading the instruction panels and information first. This can result in misunderstandings when visitors engage with the interactive exhibits. They suggested that this problem can be solved by developing tools (paper-based or digital) that allows visitors to access this information just-in-time.

Difficulties in understanding the context of the science on display was also identified as a problem by museum staff. The science museum has applied many strategies in designing and displaying various media in order to communicate science knowledge through the exhibits for general visitors. However, it seems that some of the text panels and the interactive exhibits do not allow family visitors to learn effectively. Museum staff believed that one of the obstacles to leaning about science through exhibits in the science museum is the level of language used, understanding of which depends on the science literacy level and educational background of the family members. Although the literature recommends writing museum text for an average reading age of 12 (Dean, 1996; Serrell, 1996; Tilden, 1957) and text panels in the science museum are significantly more complex and therefore hard to understand for the general family visitor.

Museum staff saw this as the reason why family visitors are requesting that more facilitators be available in the galleries and explained that, normally, there are two to five volunteers on each exhibition floor, a number adequate to cover the needs of general visitors. However, over the previous two years, the number of volunteer facilitators in the museum had declined significantly meaning that sometimes there were only one or two facilitators on each floor who were as a result unable to cover visitor demand. Some museum staff, however, noted that making more facilitators available should not be a priority solution, as family visitors generally prefer to interact within their family group rather than engage with facilitators. Consequently, other solutions should be sought that fit not only the family learning needs but also their needs to keep their visit ‘private’.

In conclusion, Thai family groups seem to visit the science museum to spend their leisure time on a fun experience that allows them to acquire basic knowledge about science and technology. The family's itinerary through the exhibitions and the exhibits that the family stops at are determined by both parents and children. The parents mostly assume the role of facilitator, and sometimes of learners. Problems with misunderstanding exhibit content result from the language used in text panels and other interpretive media, which is unsuitable for family groups; as well as the fact that families tend to ignore written instructions before engaging with the exhibits. The availability of museum facilitators was identified as a solution to these problems by families, but was disputed by science museum staff who thought that such interactions would intrude on other aspects of the family visit.

## Further Provision that Families want from the Science Museum

As well as identifying problems with current provision, the needs analysis also focused on additional provision that families would like to see from the Science Museum**.** All participants were asked to make suggestions about improvements to museum exhibitions and services that they believe would help family visitors to engage with, and learn about, science, and how the museum can better engage family audiences.

All interviewee groups stated that the science museum should focus on the development of media or tools that are specifically designed for families. The tools should provide extra information on the exhibits by using simpler language in the explanations and connecting the science behind the exhibits to everyday life and activities. This can support and encourage families to engage more confidently with the interactive science exhibits in the science museum. Most of the participants agreed that available media or tools should provide and enhance enjoyment and create opportunities for the family to participate together. Moreover, interviewees also suggested that it would be very helpful if the tools not only enhance and inspire the family to learn about science during the visit, but are also able to help the family remember the experience after visiting the science museum. Additionally, with regard to the suggestion about how the science museum can encourage more family visitors to visit the National Science Museum, all of the participants strongly recommended that the museum should pay more attention to public relations and advertisements in particular with regard to information about exhibitions and museum activities as well as basic information about visitor services.

## 4.8 Recommendations for Mobile Tools to support Family Learning

Most family groups were not familiar with the term ‘Mobile Learning’; but when the interviewer provided them with an example how families might use mobile technology in the museum, they responded positively to the prospect of using mobile devices as additional tools on their next visit.

Unlike family visitors, museum staff and mobile developers were already familiar with the term ‘Mobile Learning’ and agreed that it could be a good opportunity for the museum to develop mobile-based technology in the museum gallery as an additional service.

Six significant suggestions were made by all participants. First, that it would helpful if the science museum’s mobile application provided instructions about how to use and operate the interactive exhibits. Such instructions would encourage family visitors to interact with the exhibits with more confidence. Second, that the mobile applications should provide additional visual material (pictures) related to the exhibits and more examples that demonstrate the science behind them. Third, that running narratives of the exhibits would encourage them to engage. Fourth, that the science museum’s mobile application should be able to show related media such as moving pictures, video etc., which would allow visitors to better understand the more difficult scientific concepts. Fifth, that the mobile application should show maps and directions with the highlights of the exhibitions clearly marked, as this could help orientate and guide visitors when in the gallery. Sixth, that the science museum’s application should provide museum news and a calendar of activities and events that can be easily accessed at any time in the museum but also at home.

All of the participants were of the opinion that a mobile application would be helpful with interactive exhibits that present difficult scientific concepts and are complicated to operate and use. Moreover, the science museum staff suggested that a mobile application would also be helpful for interpreting static exhibits (e.g. in showcases or exhibits of models) that are less interesting to visitors due to the lack of interactivity and the limitations of the display area, the space and the interpretation options. Science museum staff suggested that the application could remove some of these limitations and provide more information about the objects displayed in showcases and provide visitors with opportunities to interact with static displays and collections.

## 4.9 Implications of family needs analysis for mobile learning solutions

This concluding section presents the implications of the family needs analysis findings for the mobile technology solutions. The key themes discussed above will be looked at through the lens of a mobile tool that can support families on their visits. The result of this exercise is a design framework for such a tool, one which outlines the key functions of mobile support for family science learning at the National Science Museum.

***Design framework for the development of a mobile application for family visitors to the NSM***

According to the findings from family needs analysis, there are many aspects of the family experience in the museum that present opportunities for support by a mobile application. Firstly, one of reasons for families to visit the museum is to enhance their children's science learning. The parents value the science museum as a place for out-of-school learning for family members. In this regard, the mobile application should be designed to support family visitors with informative and reliable scientific content. Secondly, the identified need for support in operating exhibits and the difficulties experienced in the understanding scientific content of currently available interpretive media combined with the lack of museum facilitators to compensate for the first two, point to a mobile application that addresses these issues of the family experience. The mobile application could be a family guide that addresses the family's needs in these respects by providing (a) information on how to operate the exhibits in the gallery, (b) additional interpretive material in a form that is easy to comprehensible and can help families understand the scientific content of the exhibits while encouraging within-family interactions, and (c) information about the contents and physical layout of the museum and its galleries.

***In conclusion, the mobile applications should:***

1. Support family visitors with accurate and reliable scientific content.
2. Provide instructions about how to operate and use the exhibits in the gallery.
3. Offer additional scientific content about the exhibits.
4. Provide information about the content and layout of the museum and its galleries.
5. Be customisable to suit the learning needs of the family.
6. Encourage family engagement and interactions within the family group as well as with the scientific exhibits.

These above requirements for the science museum mobile application point to three main functional requirements (Sharples *et al.*, 2013) for the mobile application:

- A map of museum galleries and exhibitions, including clear directions how to reach them.
- An interface with the science exhibits that offers additional multimedia information and operating instructions.
- A calendar of museum activities, news and events that allows visitors to plan their visit.

The next chapter describes the subsequent development of the museum application.

# CHAPTER 5 :
# MOBILE APPLICATION FOR NATIONAL SCIENCE MUSEUM, THAILAND

## 5.1 Introduction

The analysis of family learning needs in the Science Museum, Thailand (NSM) that was presented in Chapter 4, provided a framework for the design of a mobile tool (app) to support the science learning of Thai families during their visits to the Science Museum.

Following development of the app, it was subsequently evaluated with visiting families in the museum to assess its impacts on the families learning experience. Although the app covered a number of exhibits in the museum, four of these were selected as the focus of the subsequent evaluation, which is discussed in Chapter 6. Therefore, as well as describing the structure and functions of the app, this chapter also describes and discusses theses four exhibits and how the app supports family interactions with them.

## 5.2 The Selected Science Museum Exhibits

According to the findings from the interviews with participating families and NSM staff that were presented in the previous Chapter, there are many opportunities for mobile tools to contribute positively to the family visit, adding more layers to the family experience. Research found key problems that cause concern with regard to the information provided in the gallery through text panels and other media in relation to certain types of exhibits, in particular interactive exhibits, models, and showcases that display objects .In order to examine how well these concerns can actually be dealt with through mobile tools, four exhibits were selected as focal for this study, three located on the third and one on the second floor of the Science Museum. The chosen exhibits are: a model of Lucy, the Whisper Dishes, the Plasma ball, and a showcase that displays a Camera.

### 5.2.1 Lucy

Lucy is a model reconstruction inspired by the discovered remains of the human ancestor *Australopithecus afarensis* (Figure 5.1). This is one of the most popular exhibits for visitors of the science museum. Standing in the middle of the second floor, it provides information through small text panels, while the press of a button plays related audio interpretation. This exhibit portrays the story of the human evolution as well as giving more specific information about Lucy. The model shows what this extinct hominin would look like when she was alive between 3.9 and 2.9 million years ago. The exhibit attracts visitors not only because it is the first exhibit on the second floor and its design is eye-catching, but also because it provides viewing angles from 360° thus allowing a large space for many visitors to view at the same time. However, the drawback of this exhibit is its location: Lucy's interpretation is predominantly audio-based, yet so are other exhibits that surround her. Combined with noise from the large number of visitors that the exhibit attracts, these make the all-important audio difficult to hear.

*Figure 5.1 The Lucy model (Australopithecus afarensis) (National Science Museum, Thailand, 2013b).*

### 5.2.2 Whisper Dishes

The Whisper Dishes can be found near the entrance to the third floor (Figure 5.2). This interactive exhibit demonstrates the properties of the reflection of sound waves .With 20 metres between the two dishes, the exhibit requires two people, one at each dish, to work. One person whispers into their dish while the other person listens in on the other dish, and so forth. Information about the exhibit is displayed on two small text panels, each placed to the side of a dish. This interactive exhibit is popular but can only facilitate accommodate a limited number of visitors at a time. Moreover, many visitors have commented that the exhibit needs to provide clear, simple instructions of how to use it and there have been many complaints expressed that it is difficult to observe and understand the phenomena it demonstrates as they relate to sound waves which cannot be observed. Another drawback of this exhibit is that, like Lucy, it is located in a very loud and noisy area.

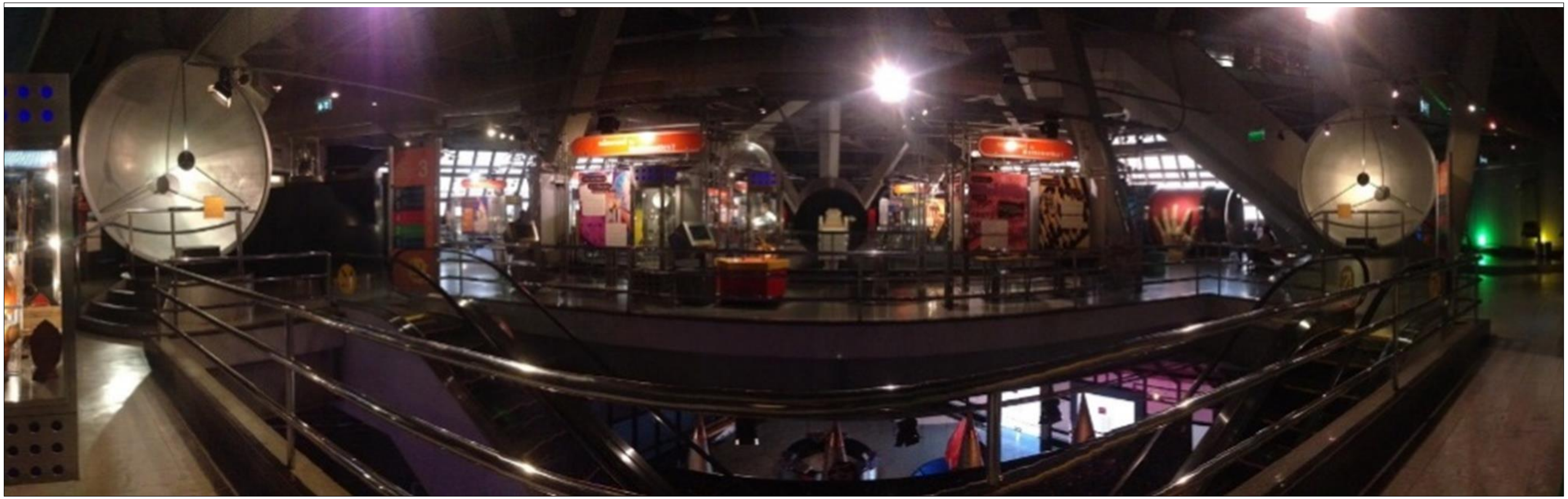


*Figure 5.2 The whisper dishes exhibit.*

### 5.2.3 Plasma Ball

The Plasma ball exhibit (Figure 5.3) is also located on the third floor and is one of the most popular exhibits of the Science Museum. It demonstrates the phenomenon of plasma state inside a glass globe on a small table. Its appearance resembles many colourful lightning bolts growing and moving inside the sphere, and attracts visitors as it is an unusual phenomenon that looks familiar to their daily lives .Most of the visitors love to touch the sphere and many of them spend a long time interacting and taking pictures of and with it .As this exhibit is of a small size (its dimensions are approximately 50x50x120 centimetres) it cannot accommodate many visitors at the same time and, given that visitors tend to spend a long time with it, traffic and long waits are generated around this exhibit at peak times .Visitors also commented that this exhibit does not provide sufficient information or other examples that would aid them to better understand this unusual phenomenon.


*Figure 5.3 The plasma ball exhibit.*

### 5.2.4 Camera Showcase

The selected showcase is also situated on the third floor and displays seven objects that are related to the phenomenon of light (Figure 5.4), specifically products whose operation is based on the properties of light. The Showcase is located on the path that leads to the Light Exhibition which demonstrates the properties of light inside a dark tent. This two-metre tall glassed cabinet displays static objects with tiny labels next to each item. The intended aim of the showcase is to extend knowledge and provide example applications of knowledge about the properties of light. However, few visitors show interest or spend time at the showcase, which has some obvious drawbacks: the lack of space and limited information given hinders learning, as there is no opportunity to provide long or detailed information and no opportunity to interact with the objects or the light properties they utilise.

*Figure 5.4 The exhibit of cameras in the showcase.*

In conclusion, the four museum exhibits discussed above were chosen as focal exhibits for this research: one model, two interactive exhibits, and one showcase. The selected exhibits were specifically chosen because of their interpretation and science communication shortcomings, to demonstrate how a mobile application for family visitors that is developed based on a family learning needs analysis, can support families in learning science in an exciting and modern way.

## 5.3 The NSM Mobile Application

In 2013, the researcher designed a mobile application based on the analysis presented in Chapter 4. The findings from the family learning needs analysis and the design framework presented there guided the structure of the mobile application. The development of the app was undertaken as a collaborative project between the National Science Museum, Thailand and the National Electronics and Computer Technology Centre (NECTEC) Thailand, which in early 2013 signed a Memorandum of Understanding (MOU) to co-operate on a number of educational projects. One of these projects was the mobile app for the NSM's family visitors. As the Museum's science educator and communicator, the researcher was involved in the project as a key person to develop the context and contents of the mobile app. Three main teams were involved in this project: the Museum's IT (Information Technology) unit, the content and application structure team (led by the researcher), and the software development team. The IT Museum unit played an important role in terms of technical support with the software and hardware infrastructure (such as setting up the database and links to the domain server). The science communication unit, as part of the content and application structure team, provided content about the museum's exhibits and defined the functions and structure of the mobile app. The software development team were supported by NECTEC to develop the app based on the information, concepts and structure of the application provided by the science communication unit.

The first version of the mobile app was launched in the museum gallery in July 2013 as a native app, i.e. an app that needs to be installed on the mobile device and can then run as standalone. One of the benefits of native apps against responsive websites, is that once the mobile application is installed, it can then be launched effortlessly without the need to type in a URL (Uniform Resource Locator) or browse a website to access to the application, allowing easy access to visitors while in the museum as well as after their visit.

The NSM app comprises two parts, the front end and the back end. The front end is the part of the application that end users directly interact with. It offers a window for the users to see what is inside the program and gives them access to the app's functionality. The back end is the part of the application that is accessed by authorised museum staff only to manage the content and arrange space for the application and support the front-end services. In a sense, the front end of the app is like a finished exhibition that can be updated, while the back end is like a workshop.

The first version of the app was created for the Android operating system only. Four months after the deployment of this first version, a second version was rolled out, which for both iOS and Android operating systems. Positive feedback about the first version from both visitors and museum staffs, the development of the second version of the app was supported by the organisation's management board and we were encouraged to expand the project in order to support visitor learning in the other museums. Thus, the second version of the app covers the Science Museum, the Information Technology Museum, and the Chaosamphraya National Museum. The app was renamed *Museums Pools* and essentially combines three apps from three museums in one place. However, the context and content of each application is tailored to each museum. Due to the success of the first version, the second version of the Science Museum's app retained the main features and contents. Some material was added, such as a video and a cartoon animation in order to support family learning needs and further extend understanding of the scientific context in the gallery.

The focus of this research remains the family groups of visitors who visit the Science Museum, therefore the Science Museum app only is discussed below.

### 5.3.1 Structure and Functions of the Application

In her role as a long-standing science educator and science communicator at the NSM, the researcher led the content and application structure team for the development of the app. The main principles behind the design of the application are: to connect to the database easily, be user friendly, be informative about the museum, offer additional knowledge about exhibits inside the museum, and facilitate user interactions. Following these principles, and implementing the design framework presented in Chapter 4, the application was designed with functionality under four main menu items: ‘map’, ‘calendar’, ‘highlight exhibits’ and ‘QR code interface’.

The application was made available to download directly from the museum website, either before the visit or at the museum lobby. To begin using the application, a family member needs to login or register as a new user (Figure 5.5). After the login process is complete, the application directs the user to the main menu, which consists of the 4 items described above (see Figure 5.6).

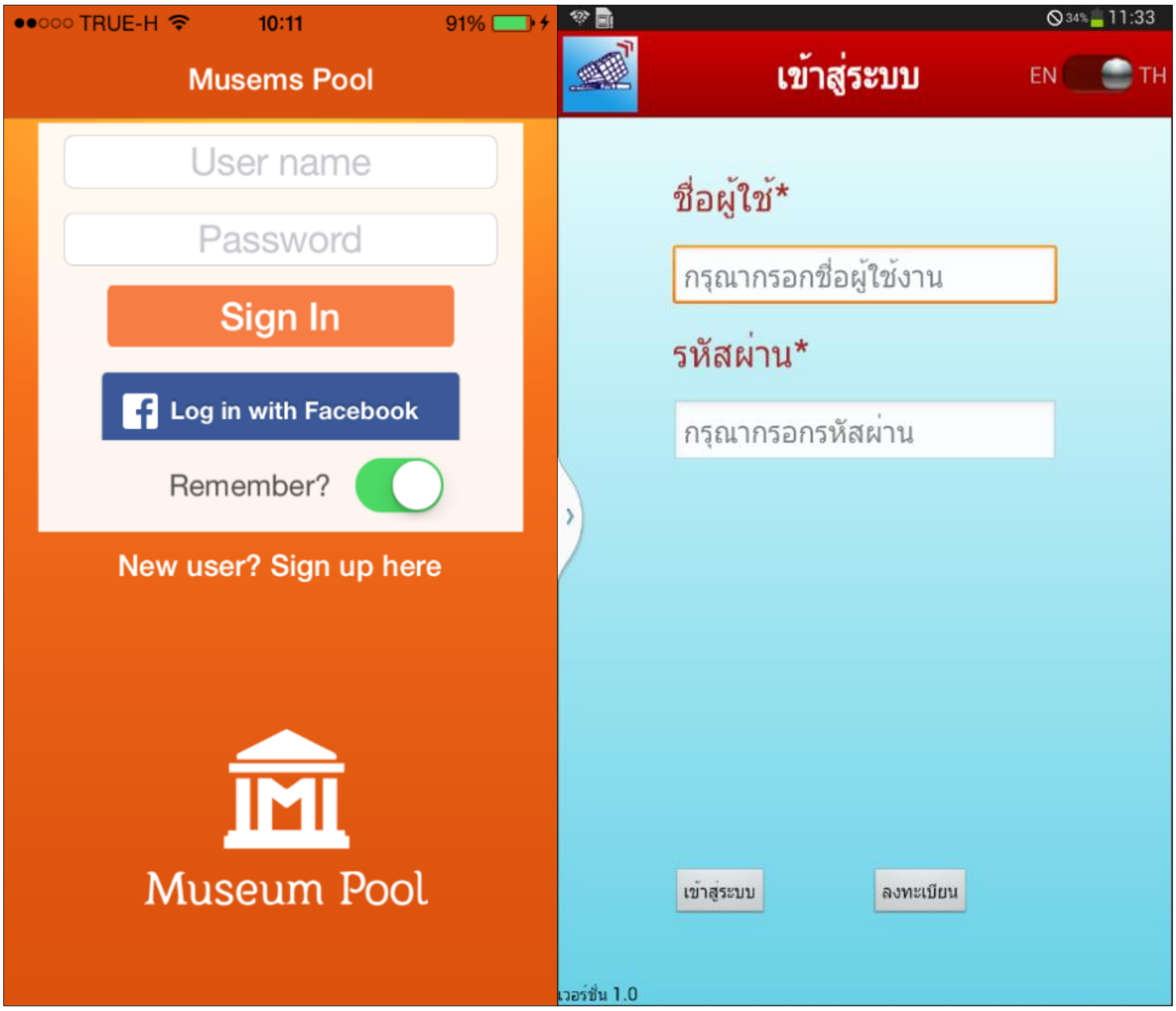



*Figure 5.5 Registration and login pages of the NSM application.*

*(Left: the first version, right: the second version)*

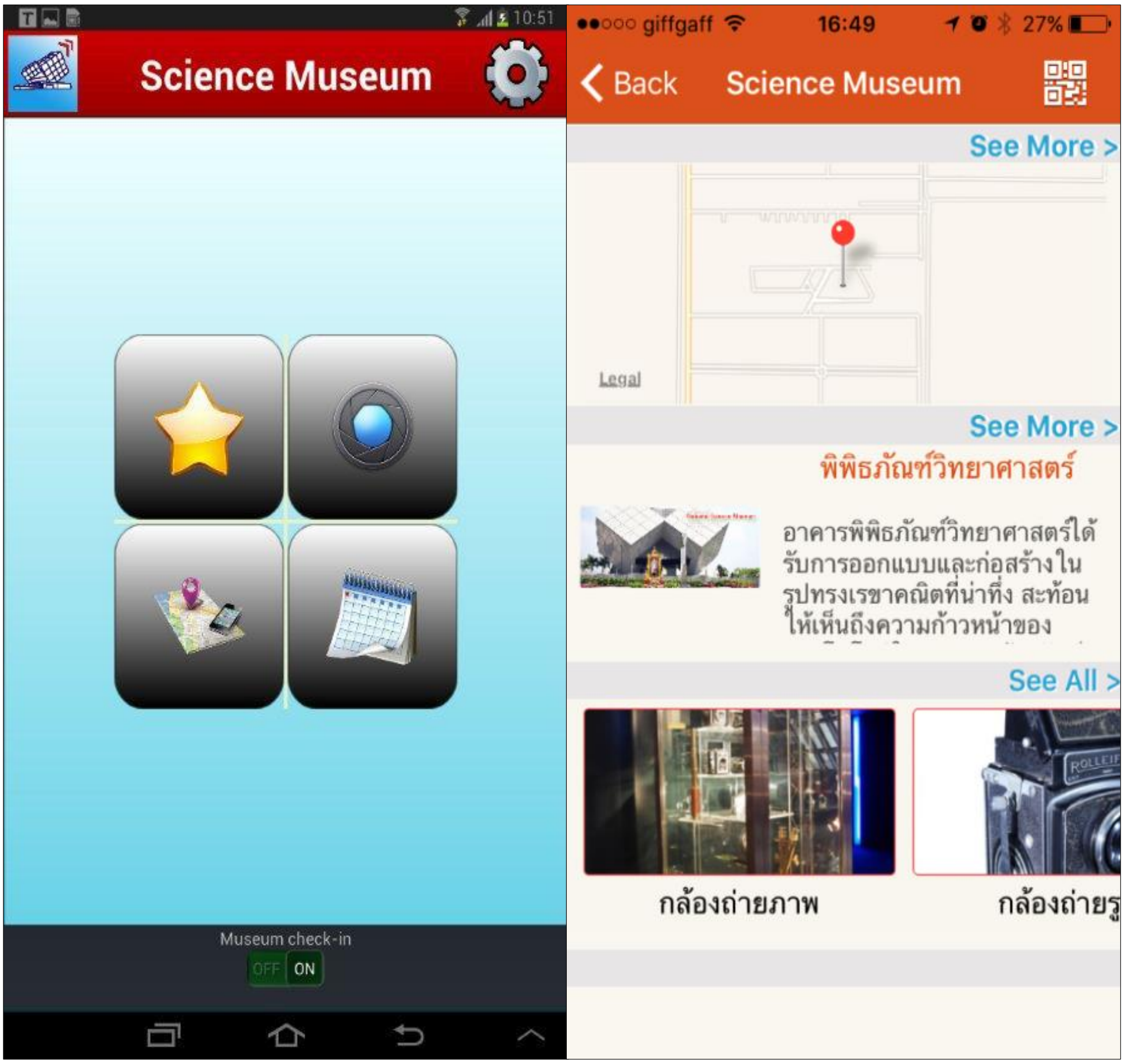



*Figure 5.6 The four main menu items of the first version (left) of the NSM App and the main page of the Science Museum application in Museum Pool app.*

From figure 5.6 the four main menu items of the first version which are Highlight Exhibits on top left, on top right is the QR Code Interface (camera for QR code exhibits interface), on bottom left is Map and location, and on bottom right is the Event Calendar. For the second version on the right, each menu shows as one banner, Map, Museum's information and event, Highlight Exhibits are arranged from the top of the screen and the QR code interface is on the top right of the screen.

In terms of location of use, the application operates in two modes. Outside the museum, the app allows visitors to access only general information about the museum, the events calendar and a map with directions to the museum. In this mode, visitors can gain general information about highlight exhibits, receive museum news and events (to know what is on, when and where), directions to the museum, opening times and admission fees. This allows visitors to plan their visit in advance. Inside the museum, the app allows visitors to access all of the menu items, including the camera and the QR code interface functions (see top right of the menu window in Figure 5.6 (left) above) that allows the user to interact with exhibits through QR codes in order to get more information about the exhibits. In order to activate the QR code function, visitors need to connect their device to the museum network via the museum's free WiFi connection.

As this was a new service from the National Science Museum Thailand, the science museum provided both instruction panels and museum staff in order to assist visitors with installing and using the app effectively. The museum provides a space near the entrance of the building for the visitors to learn about, get help with and gain more information about the new service (Figure 5.7). Moreover, not only Science Museum staffs assist but a large panel and leaflets are provided, describing what the app is, how it works, how to download, install and use it (Figure 5.8). However, visitor engagement with the app is voluntary.


*Figure 5.7 Science Museum's application information corner.*


*Figure 5.8 Science Museum's application information panel.*

**The Main Functions of the NSM Mobile App**

**Function One: Exhibition Highlights**

This function was a result of findings from the family learning needs analysis (Chapter 4). Visitors asked for a tool that could help them make decisions about what to see in the museum. By providing short descriptions and general information about exhibits, the Exhibition Highlights function aims to assist visitors by introducing to them the most attractive science exhibits in the Museum. As visitors had also expressed concerns about the difficulty level of the in-gallery interpretive media, this function also serves to provide background information, preparing them to search for deeper information before or during a visit.

In total nine exhibits were selected as highlight exhibits in the science museum, ranging from static display models and cased objects, to interactive hands-on exhibits (Figure 5.9). As this menu item can also be activated outside the museum, each highlighted exhibit provides information for families in the form of a short description and related pictures (Figure 5.10) Once visitors are in the museum this function provides more descriptions, related pictures, video clips or graphic animations that help explain the scientific content, while in explore mode it can guide visitors by giving them directions to the exhibit (Figure 5.11). In addition, when at an exhibit, this content can also be accessed through a QR-code, avoiding the need to navigate to the content. This can be done by using the camera feature in the application to take a photo of the QR code that is available at the exhibit (Figure 5.12).

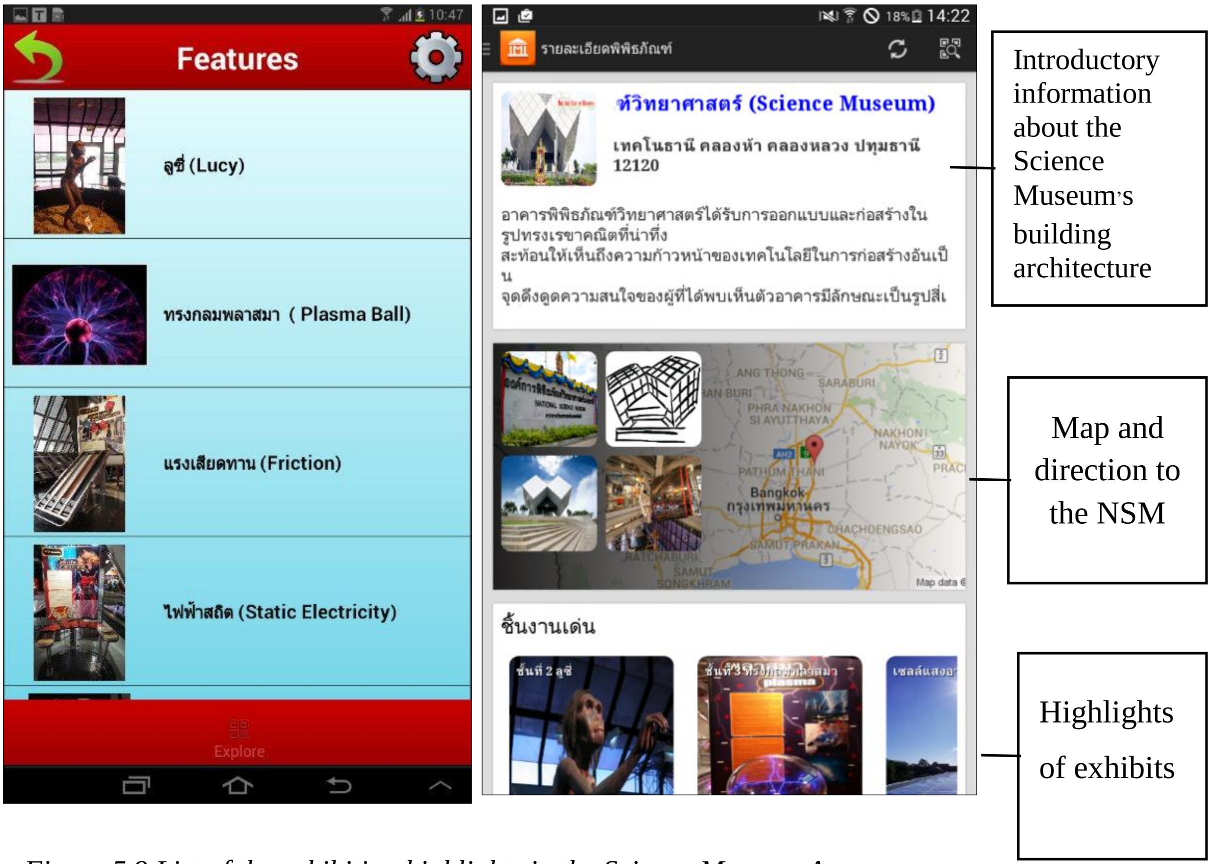



*Figure 5.9 List of the exhibition highlights in the Science Museum App.*

*Left: the first version, Right: the second version, the list of the highlight exhibits is located at the bottom banner of the first page.*

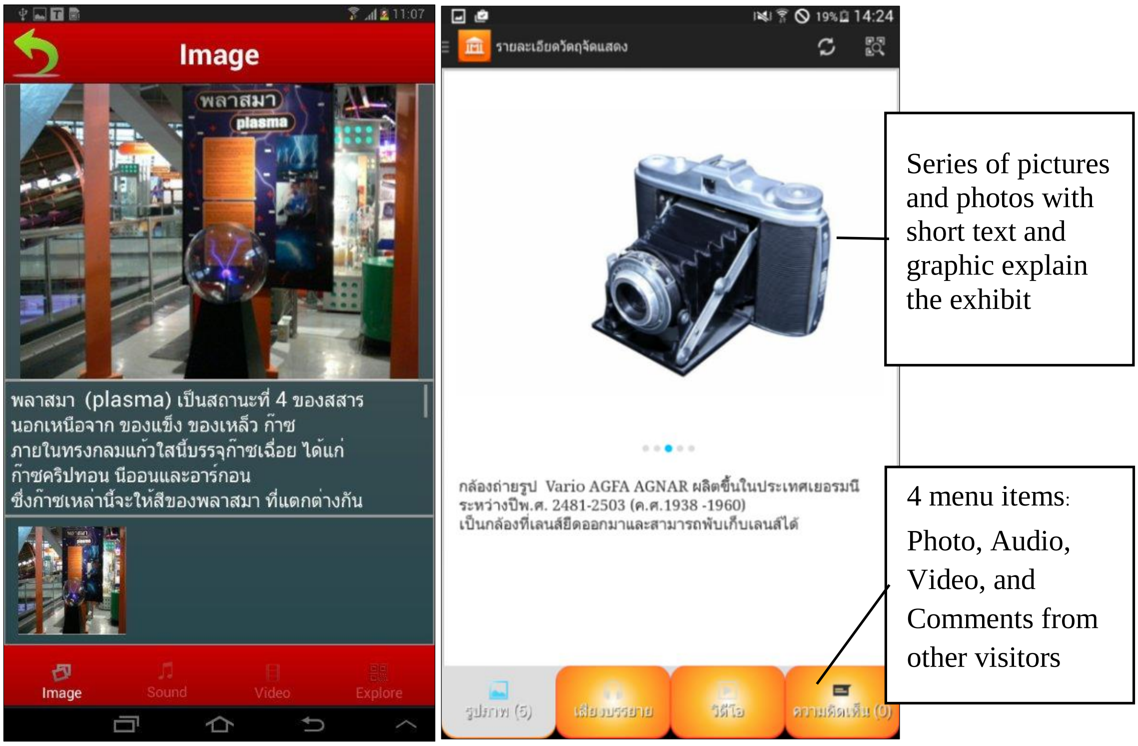



*Figure 5.10 The highlight exhibit details.*

In each highlight exhibits the first page provides a short description and related pictures when the visitors use the App not in the museum. The bottom menu bar (red for the first version and orange for the second version) only shows image icon until inside the museum (left: the first version and right: the second version).

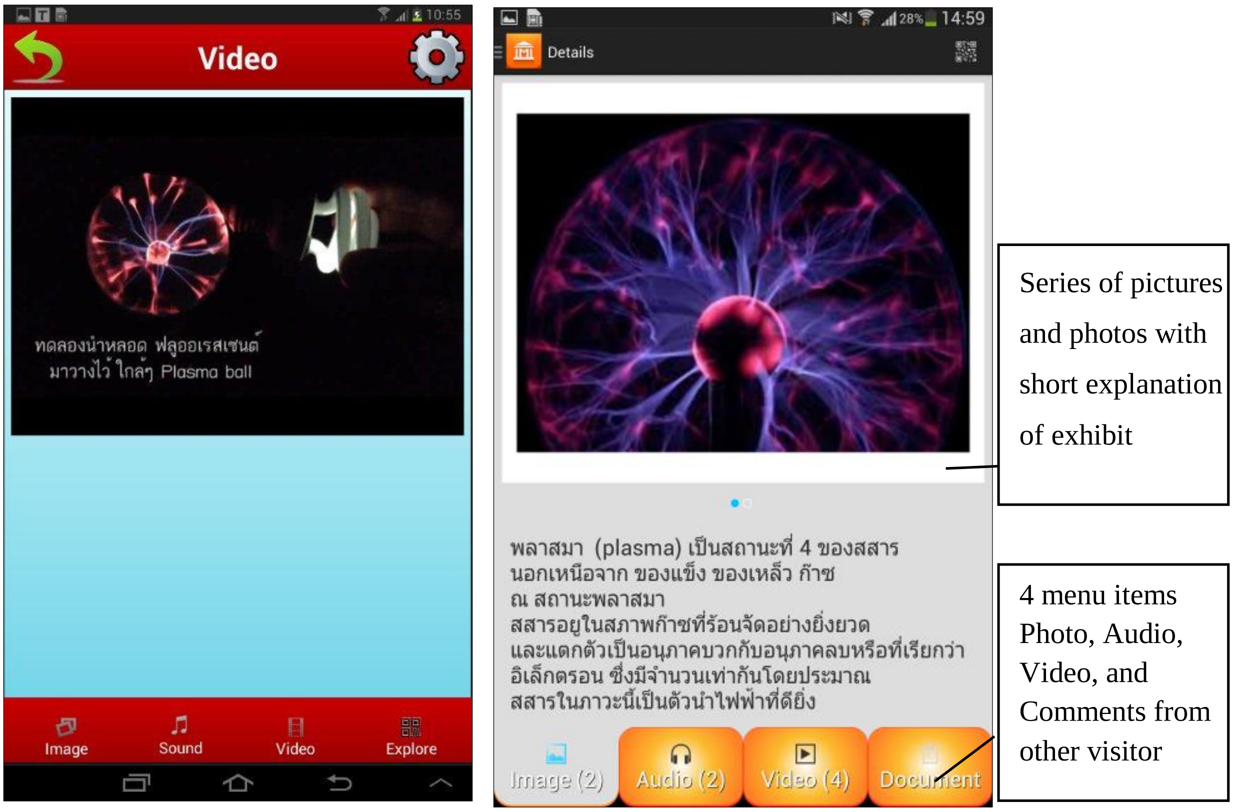



*Figure 5.11 The exhibit highlight details.*

When visitors are inside the museum, this function is activated and the bottom menu bar will show the activated icon from all four icons; Image, Sound, Video and Explore (Document icon for the second version) tabs.

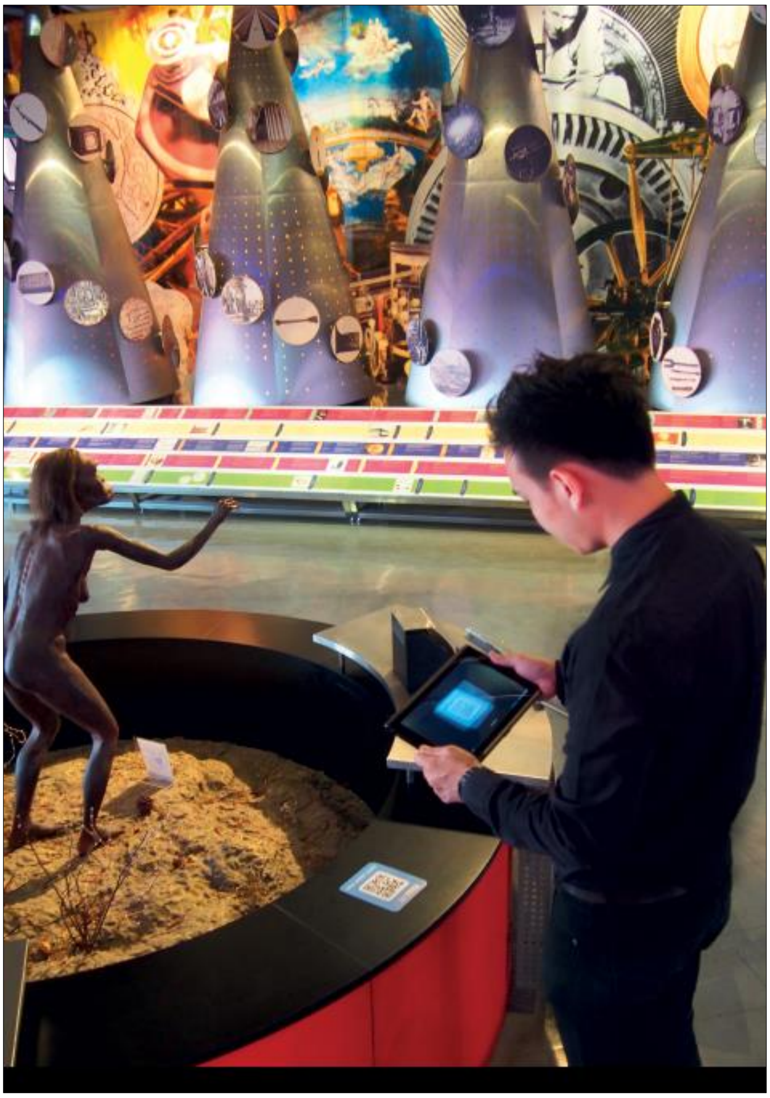


*Figure 5.12 Using the QR code to access information about the Lucy model.*

**Function Two: Map and Floor Plan of the Science Museum**

In the needs analysis study, visitors commented that they got lost trying to find the Science Museum, which is on a large campus where three very large museums are co-located. There are several other science related institutes located in the same region (Pathum-Thani) such as Science Park, Rangsit Science Centre for Education, Rangsit Planetarium, the National Geological Museum. The Map offers directions to the museum from anywhere in Thailand. This function can help visitors to plan their travel to the museum easily and provides general service information about the museum, such as opening hours and admission fees (see in Figure 5.13).

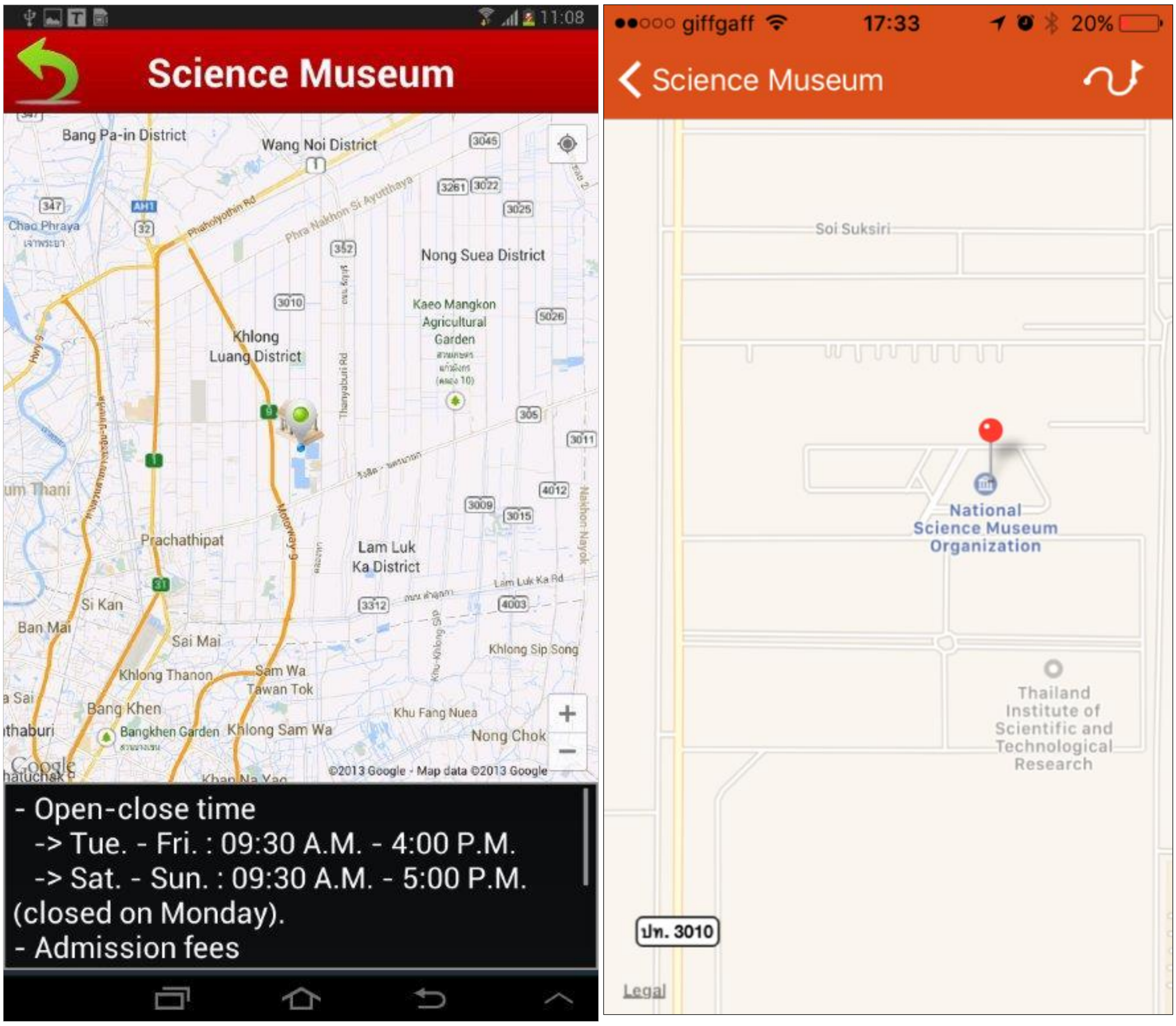
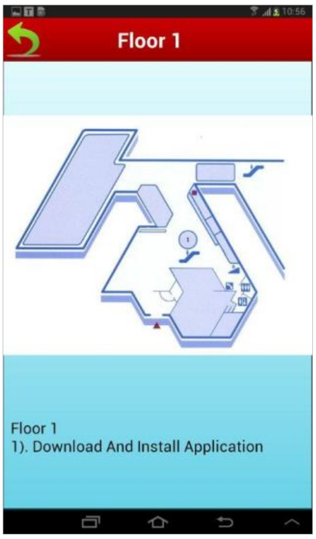


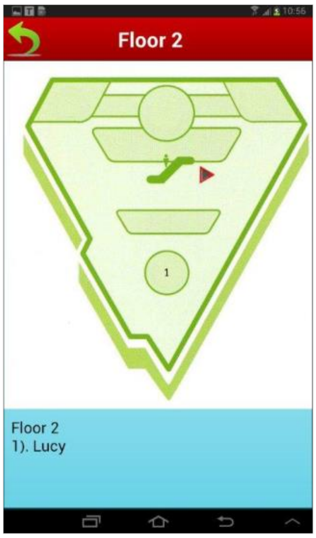

*Figure 5.13 The Map, showing directions from the user's current location to the museum (Left: the first version, right: the second version).*

When the visitor is inside the Science Museum, the Map button will instead display museum floor plans and exhibition guides. The change takes place when the visitor enters the museum and connects to the museum's network. This page will help the user to navigate the museum gallery by showing the floor plans and marking positions of highlighted exhibits or other prominent points in the exhibition. The application provides plans of all three museum floors, each in different colours for easier recognition.

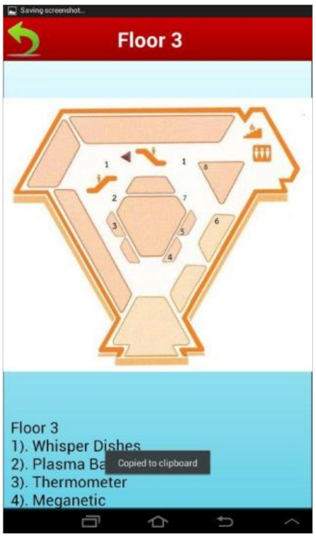

(a)




(b)




(c)




(d)

*Figure 5.14 The exhibition's floor plan displays highlight exhibits on each of the three floors.*

This function will be activated when visitors are in the science museum and connect their mobile device to the museum's network.

**Function Three: The Camera and QR Code Interface.**

Findings from the family learning needs analysis indicated that there is a notable lack of instructions on how to use exhibits, many difficulties in understanding scientific content from the exhibition (which could be due to multiple reasons), and lack of facilitating staff in the gallery where further information is needed. This function helps to address these issues.

The function is available only when visitors have entered the museum and have connected to the museum's network. After the App has changed mode to 'inside the museum', the camera and QR code function allows visitors to scan the QR code at the exhibits for extended information about each exhibit. Available material include pictures, texts, video clips, graphic animations and audio narrations that relate to the exhibits. This function has potential both to communicate scientific information and contribute to visitor understanding; and to provide an appropriate 'instruction manual' that support visitors to explore and experiment with the interactive exhibits in a personal way.

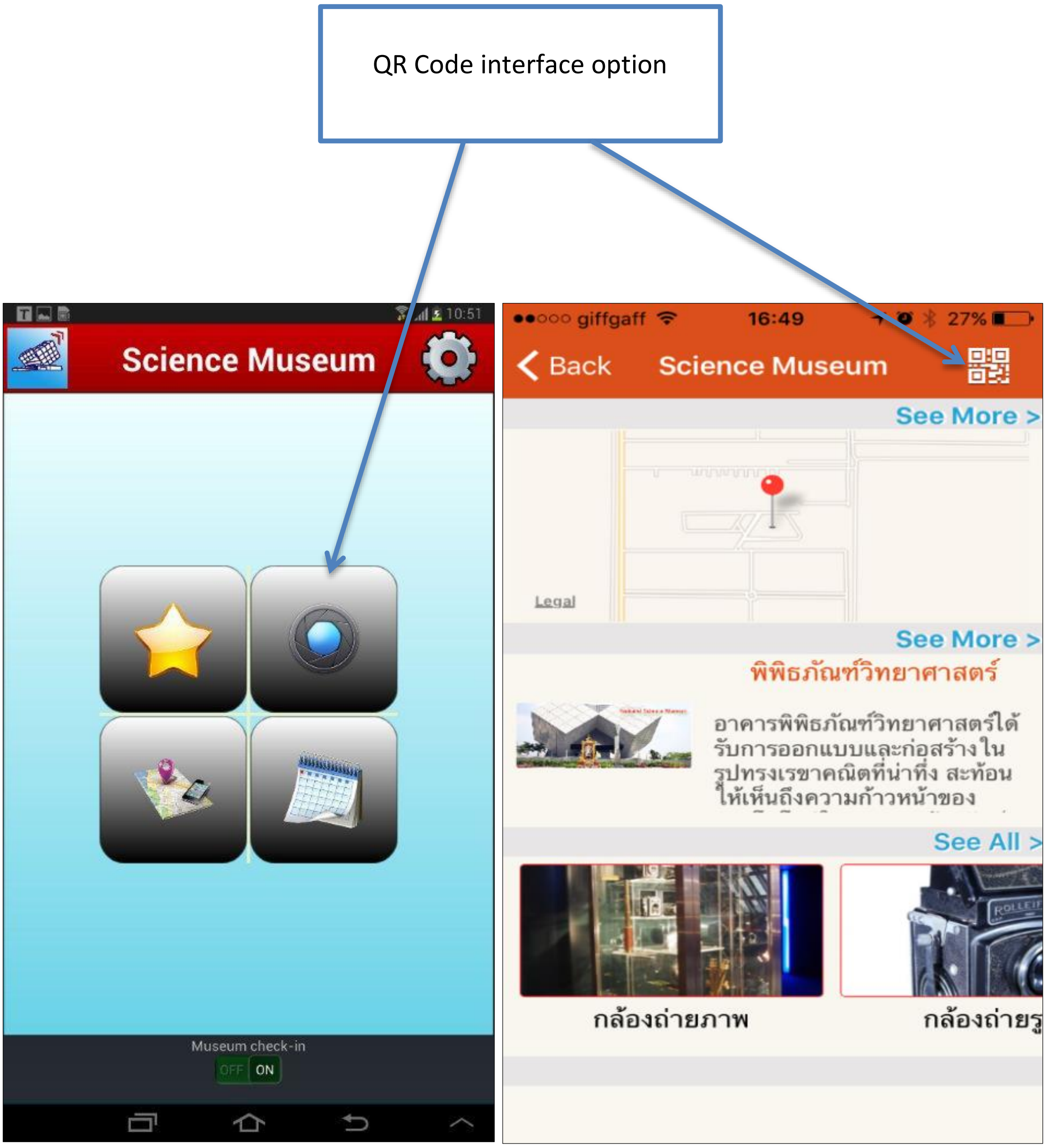



*Figure 5.15 An icon for the QR code interface menu (camera mode).*

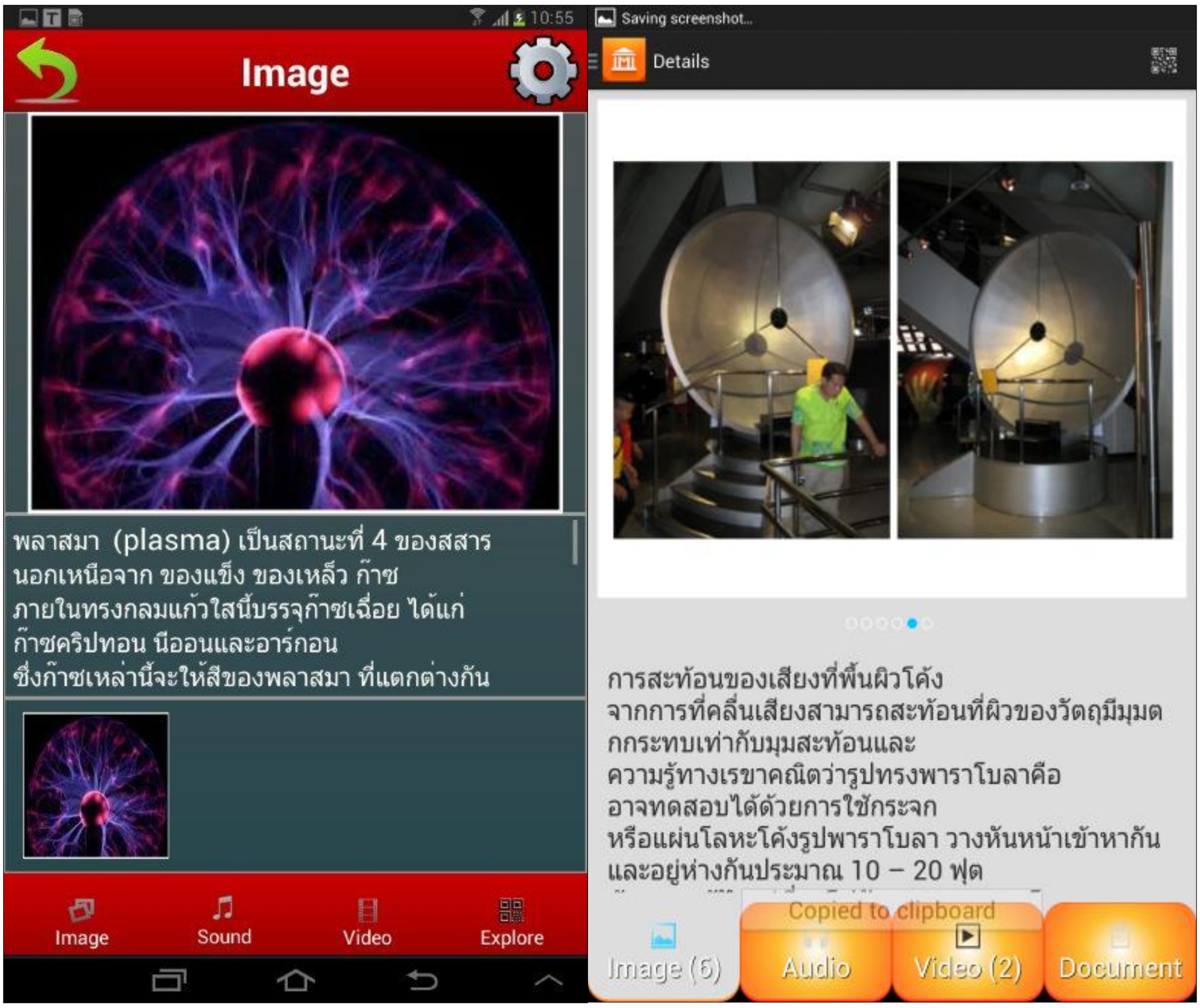



*Figure 5.16 The extended information page.*

*(This page shows more materials available at the bottom bar).*

**Function Four: NSM Event Calendar**

This function was also derived from visitor feedback in the family learning needs analysis .Family groups strongly recommend that in order to encourage and engage more family groups, more attention should be paid to the strategy of providing information on museum products, exhibitions and activities as well as basic information about the visitor service. This function was created with the main objective to inform - with museum news, basic information, events and activities for visitor. Such information may encourage family visitors to plan and make a decision to visit the Science Museum.

The calendar links to an up-to-date list of museum events and provides more information about things that are going on in the museum.  These include temporary exhibitions and special activities scheduled for families, such as the Science Show, Science Lab, Science Camp as well as special activities in the museum galleries (Figure 5.17). The museum's activity function mode will bring up the museum calendar page that allows visitors to plan the day, with activities they would like to do and exhibitions they would like to explore.

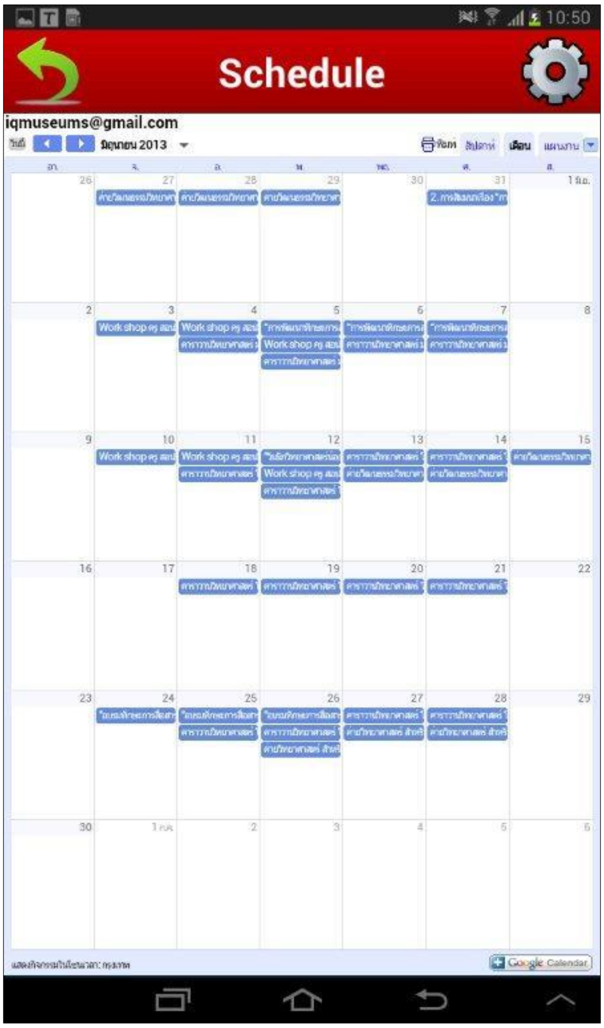



*Figure 5.17 Calendar of upcoming events in the museum.*

### 5.3.2 The Back End: Management and Maintenance of App for Staff

The back end is a crucial part of the mobile application. This part is used for creating and managing content, uploading materials and general maintenance of the application (Figure 5.20). It is an area that only authorised staffs are allowed to access. This application back office runs through the Content Management System (CMS), Word Press. The back end platform was designed and developed in co-operation with the National Electronics and Computer Technology Center (NECTEC) for use by museum curators and staffs.

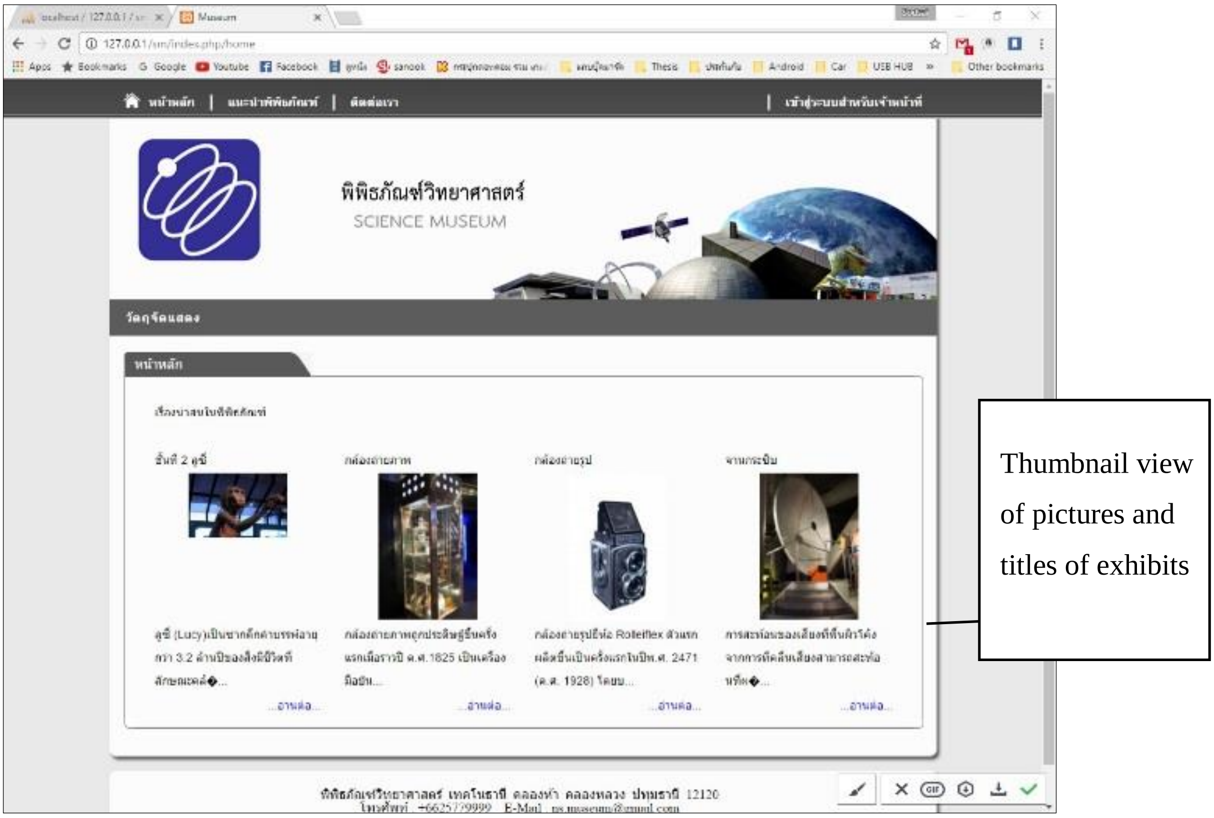



*Figure 5.18 Main page of the back office of the NSM. mobile application.*

*Figure 5.19 Exhibits' detail page in back office of the NSM mobile application.*

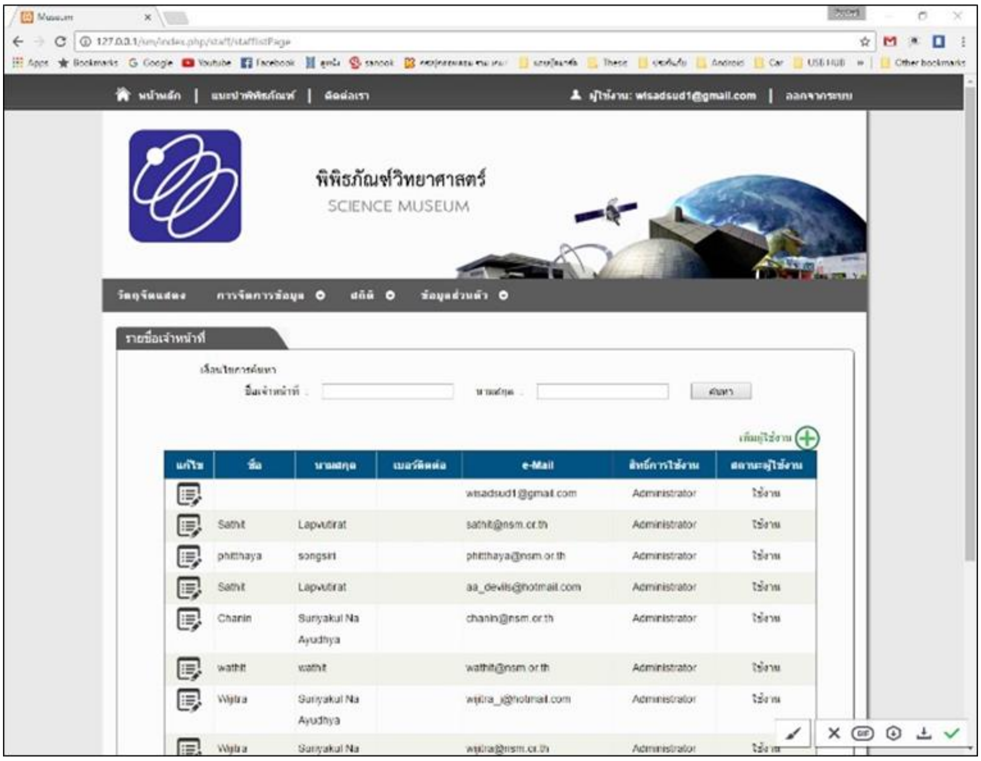


*Figure 5.20  List view of the exhibits on display in highlight in back office of the application.*

## 5.4 Conclusion

It is clear that the app development was based on the findings from the family learning needs analysis. The four main exhibits that were selected as case studies for testing in the summative evaluation were; Lucy, Plasma ball, Whisper Dishes and Showcase. The decision to select these particular four exhibits was made to help family science learning needs and solve identified problems with the interpretation of these certain types of exhibit. For example, to help with instructions of interactive exhibits (Whisper Dishes) and provide additional scientific content needed for the static display models and objects (Camera Showcase).

In April 2015, a summative evaluation was conducted with the aim to assess and understand the effectiveness and usefulness of this mobile application as well as the impact of its use in family science learning environments. Data analysis and the findings of this research will be presented in Chapter 6.

# CHAPTER 6 :
# FINDINGS FROM THE SUMMATIVE EVALUATION

## 6.1 Introduction

This chapter presents the findings from the summative evaluation of the mobile application (App) that was developed for this research. As described in Chapters 4 and 5, the development of the mobile application was based on the family learning needs analysis conducted through the preliminary research for this study. In terms of science learning within the family museum experience, the conceptual framework and structure of the application aims to facilitate and engage family groups visiting the National Science Museum, Thailand. The summative evaluation comprised three main parts: a questionnaire evaluating the usability of the mobile application, participant interviews evaluating family learning outcomes, and video-based observations of family behaviours during their gallery visit at selected exhibits evaluating behavioural engagement.

Table 6.1 Number of Families per Data Collection Activity

| Group* | Usability evaluation | | | Learning outcomes interview | Video-based observation |
|---|---|---|---|---|---|
| | SUS | Generic usability | Generic visit | | |
| A (26) | x | x | x | | |
| B (17) | | | x | x | |
| C (21) | | x | x | x | |
| D (10) | | | | | x |
| E (10) | | | | | x |

*Groups A, C and E used the Science Museum app during their visit whereas groups B and D did not use the app.

We evaluated the app with 84 families at the NSM in April 2015 (see Table 6.1above). The families were assigned into one of five groups (A to E) depending on which weekend they were visiting. Only families in groups A, C and E used the app. These families tended to download the app on a mobile device and designate one family member as the app main user – typically an adult, although in some families the main user was a child. The usability and learning outcomes interviews sought input from the whole family group, therefore families were given the opportunity to deliberate and give answers that all family members agreed on. Thus, if for example a family's response to a question was 'strongly disagree', this answer represents the view of the whole family group.

## 6.2 Usability Evaluation

This part presents the results from the usability evaluation. Typically, usability tests are intended to determine the usefulness, effectiveness and satisfaction of the prospective users when using a new application. Results of usability evaluations aim to provide and identify potential areas for improvement of the application, particularly its user interface – the part of the application that the user interacts with. Such issues affect not only the user's experience of the mobile technology, but may also impact the learning experience that is built around or is supported by the use of the technology (Vavoula & Sharples, 2009). It is therefore critical to ensure that usability problems are identified and understood separately from more structural problems with learning support design.

This research adopted the System Usability Scale (SUS) for usability evaluation, which was developed by John Brooke in 1986. SUS was introduced as a 'quick and dirty' yet effective tool for practically testing any kind of system (Brooke, 1996). SUS comprises a short, 10-item questionnaire for the product user. Unlike other usability evaluation methods, it does not require a lot of resources to undertake. The questionnaire items can be adapted to suit the particular application that is tested. This means that, SUS is one of the most efficient tried and tested tools that can provide statistically valid data and reasonable feedback within a short period of time, with very little administration overhead.

SUS questionnaire items are presented as statements. The user can rate on a Likert Scale from 1 to 5 the extent to which they agree or disagree with the statement they are reading. Five designates strong agreement, while one designates strong disagreement. The questionnaire includes a total of ten statements, which are presented as alternating positive and negative statements about the system. Odd-numbered statements are positive, while even-numbered statements are negative. This is done to avoid wording bias in the questionnaire and to balance the presentation of positive-negative wordings. The following formula is applied to calculate the score given by a respondent to the system's overall usability out of a maximum score of 100:

$$\text{SUS score} = 2.5 * \sum_{i=1}^{5}\left((Q_{2i-1} - 1) + (5 - Q_{2i})\right)$$

where Q1 – Q10 are the average scores from questions 1- 10

The expression inside the sum reflects the alternation of positive and negative statements and transforms the ratings for the negative statements (i.e. the even-numbered questions) into equivalent positive ratings. Thus, if a negative statement receives a score of 5, meaning that the user strongly agrees with the negative statement, the contribution of that score to the overall usability score of the system will be 5-5=0. Conversely, if a user gives a score of 1 to a negative statement (i.e. strongly disagrees with it) the contribution of that score to the overall usability score of the system will be 5-1=4 which is the maximum positive contribution. Thus, the maximum score a user can give is 10*4=40. To calculate the SUS score, this number is then multiplied by 2.5, making the maximum SUS score per participant equal to 100. All participants' SUS scores are then averaged to find the overall SUS score of the system.

Research shows (Brooke, 2013) that the average SUS score is 68, therefore a score of 68 deems a product acceptable in terms of usability. If the score is above 68, then the developed system is acceptable in terms of perceived usefulness and user satisfaction. The closer the overall system score is to 100, the more usable the system is. If the overall score is under 68, then there most likely are serious problems with the usability of the developed system. For systems that support learning, like the mobile app evaluated in this study, the likelihood of serious usability problems increases the likelihood of such problems affecting the learning experience that the system (in this case, the app) supports.

On the contrary, the closer the SUS score is to 100, the less likely it is that issues observed at the level of the learning experience are due to undiagnosed underlying usability problems.

Although SUS can give an overall picture of a system's perceived usability, and although scores of individual questions can highlight generic areas of concern, the SUS method cannot give details on specific usability problems. Thus, in applying the method in this study, I complemented the SUS questions with a series of open-ended questions where participants (i.e. family groups visiting the National Science Museum) could provide more specific feedback about the usability of the mobile app (see 'Generic Usability' and 'Generic Visit' columns in Table X above). The following subsections give details of the participants, procedure and results of the usability evaluation.

### 6.2.1 Participants

The usability evaluation of the mobile application in this project was conducted through onsite interviews which were used as a method to collect data at the Science Museum. Although the second phase of the development of the app was expanded to multiple museums, the main case study remains focused on the original museum it was designed for, the Science Museum at the National Science Museum, Thailand. On the days that usability data collection took place, family participants were recruited from those visiting the museum as follows: at the entrance of the museum parents and children were asked whether they would like to use the app during their visit and take part in the study. The first family to enter the museum, after the previous family's interview had been completed, was approached. If a family did not consent to participate; the next family to enter the museum was approached. In total, 26 families (Group A) participated and were interviewed for the usability evaluation – a total of 104 family users.

### 6.2.2 Procedure

Data collection for this usability evaluation took place during weekends in April 2015, on the ground floor of the Science Museum. The first step of the procedure was to train the target users in how to use the app. After a family consented to participate in the usability evaluation, they were introduced to the NSM mobile app. A graphic panel was placed inside the museum gallery on the ground floor next to the entrance, introducing and providing information about the application (see Figure 6.1). The panels display instructions and information about the museum mobile application.

The panel included the following details:

1. An introduction to the museum mobile application and general information about it.
2. Step-by-step instructions how to install the app to help visitors with setting up their mobile device, either on iOS or Android operation systems.
3. How to use the mobile application within the gallery. In this part, keys features and functions of the application were illustrated with graphics and descriptive explanations.


*Figure 6.1 The panels display instructions and information about the museum mobile application.*

The training of the participants involved introduction of the mobile application and supporting them to connect to the museum's Wi-Fi network to download and install the app on their mobile device. After the app was successfully installed, the participants were guided how to sign up and use the app for the first time. Signing up requires the user to provide some basic information including their chosen user name and email address. They are then asked to create a password and sign in to start using the application. At this point, the mobile app was ready to use in the museum gallery and participants were then given a demonstration of keys features and functions of the app as well as how to scan the QR codes at the exhibits in order to access the media about the exhibit available in the application. This training and introduction of how to use the app took place near the introductory graphic panels shown in Figure 6.1 above, so the trainer could refer to the panels as needed and the app user could have access to a graphic overview of how the mobile app works.

Additionally, the museum also provided two tablets in case any families were interested to participate but did not want or could not use their own mobile devices.

After the participating families were introduced to and ready to use the mobile application, they were asked to use the app as a museum exhibit guide tool during their visit. At the end of the visit, each of the participating families were interviewed by the researcher face-to-face and their responses were audio-recorded, while the researcher also took notes. During the interview, the family participants were encouraged to discuss and share their feedback and answer the interview questions as a group. Families were given time to discuss between them and reach a consensus about their answers. Thus, if a family's response to a SUS question was "strongly agree", that response represented all family members.

### 6.2.3 The Interview Questions to Assess Usability

The System Usability Scale (SUS) was applied to measure the family group's opinions about the NSM app's usability. The original SUS questions presented in (Brooke, 1996) were modified to match the app tested in this study. In addition to the ten SUS questions, a second set of open-ended questions asked families about their experience of using the app, in particular any additional needs that were not met by the app and /or problems that the participants faced using the app as a tool during their gallery visit. Table 6.2 below presents the usability-related questions that were asked during the family interviews (questions 1 to 10 are the SUS questions).

Table 6.2 The usability questions.

| | Part 1: The Usability of the mobile app<br>On a scale from 1 to 5, where 1 is 'strongly disagree' and 7 is 'strongly agree', rate how much you agree or disagree with the following statements: | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Strongly Disagree** | | **Neutral** | | **Strongly Agree** | |
| | Usability Scale | 1 | 2 | 3 | 4 | 5 | Comment |
| 1. | I think that I would like to use this system frequently | | | | | | |
| 2. | I found the system unnecessarily complex | | | | | | |
| 3. | I thought the system was easy to use | | | | | | |
| 4. | I think that I would need the support of a technical person to be able to use this system | | | | | | |
| 5. | I found the various functions in this system were well integrated | | | | | | |
| 6. | I thought there was too much inconsistency in this system | | | | | | |
| 7. | I would imagine that most people would learn to use this system very quickly | | | | | | |
| 8. | I found the system very cumbersome to use | | | | | | |
| 9. | I felt very confident using the system | | | | | | |
| 10. | I needed to learn a lot of things before I could get going with this system | | | | | | |

### 6.2.4 SUS Findings

As previously mentioned, the first section of the interview implemented following the SUS method. Table 6.3 below shows the SUS scores per family as well as the overall SUS score when averaging scores from all families. Scores range from 47.50 to 97.50, with 18 scores in the acceptable range for perceived usability (above 68).

Table 6.3 The calculated SUS scores from family app users.

| # Family | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | SUS Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 97.50 |
| 2 | 5 | 1 | 5 | 2 | 4 | 3 | 5 | 2 | 4 | 4 | 77.50 |
| 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 50.00 |
| 4 | 4 | 1 | 5 | 4 | 4 | 1 | 5 | 1 | 5 | 1 | 87.50 |
| 5 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 2 | 95.00 |
| 6 | 5 | 3 | 4 | 1 | 2 | 2 | 4 | 1 | 3 | 1 | 75.00 |
| 7 | 5 | 2 | 4 | 2 | 3 | 3 | 2 | 2 | 4 | 2 | 67.50 |
| 8 | 4 | 2 | 4 | 1 | 3 | 3 | 3 | 2 | 4 | 2 | 70.00 |
| 9 | 5 | 2 | 4 | 2 | 4 | 3 | 4 | 2 | 4 | 1 | 77.50 |
| 10 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 55.00 |
| 11 | 4 | 3 | 4 | 2 | 4 | 3 | 4 | 2 | 4 | 3 | 67.50 |
| 12 | 5 | 2 | 4 | 2 | 4 | 2 | 4 | 1 | 3 | 1 | 80.00 |
| 13 | 5 | 2 | 5 | 1 | 5 | 3 | 5 | 1 | 4 | 1 | 90.00 |
| 14 | 3 | 3 | 2 | 3 | 2 | 4 | 4 | 3 | 3 | 2 | 47.50 |
| 15 | 3 | 2 | 4 | 2 | 4 | 3 | 4 | 2 | 4 | 2 | 70.00 |
| 16 | 5 | 1 | 5 | 1 | 5 | 3 | 5 | 1 | 5 | 3 | 90.00 |
| 17 | 4 | 1 | 4 | 3 | 5 | 1 | 3 | 1 | 5 | 1 | 85.00 |
| 18 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 52.50 |
| 19 | 5 | 1 | 5 | 1 | 4 | 2 | 4 | 1 | 5 | 1 | 92.50 |
| 20 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 1 | 4 | 4 | 60.00 |
| 21 | 5 | 1 | 5 | 1 | 3 | 2 | 4 | 1 | 2 | 1 | 82.50 |
| 22 | 5 | 1 | 5 | 3 | 5 | 2 | 4 | 1 | 4 | 3 | 82.50 |
| 23 | 4 | 1 | 5 | 3 | 4 | 3 | 4 | 1 | 4 | 3 | 75.00 |
| 24 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 52.50 |
| 25 | 5 | 1 | 5 | 3 | 3 | 3 | 4 | 2 | 4 | 3 | 72.50 |
| 26 | 5 | 4 | 4 | 3 | 3 | 3 | 5 | 3 | 5 | 3 | 65.00 |
| Average SUS score | | | | | | | | | | | 73.75 |

The results show that the app average was 73.8, placing it firmly within the acceptable level of perceived usability (Bangor, Kortum & Miller, 2009).

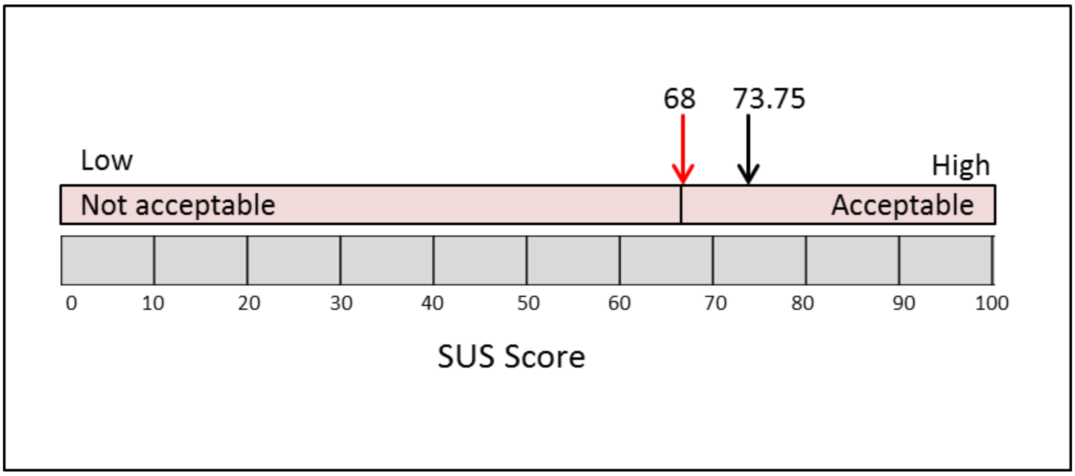



*Figure 6.2 Placing the app's SUS score on the acceptability scale for perceived usability.*

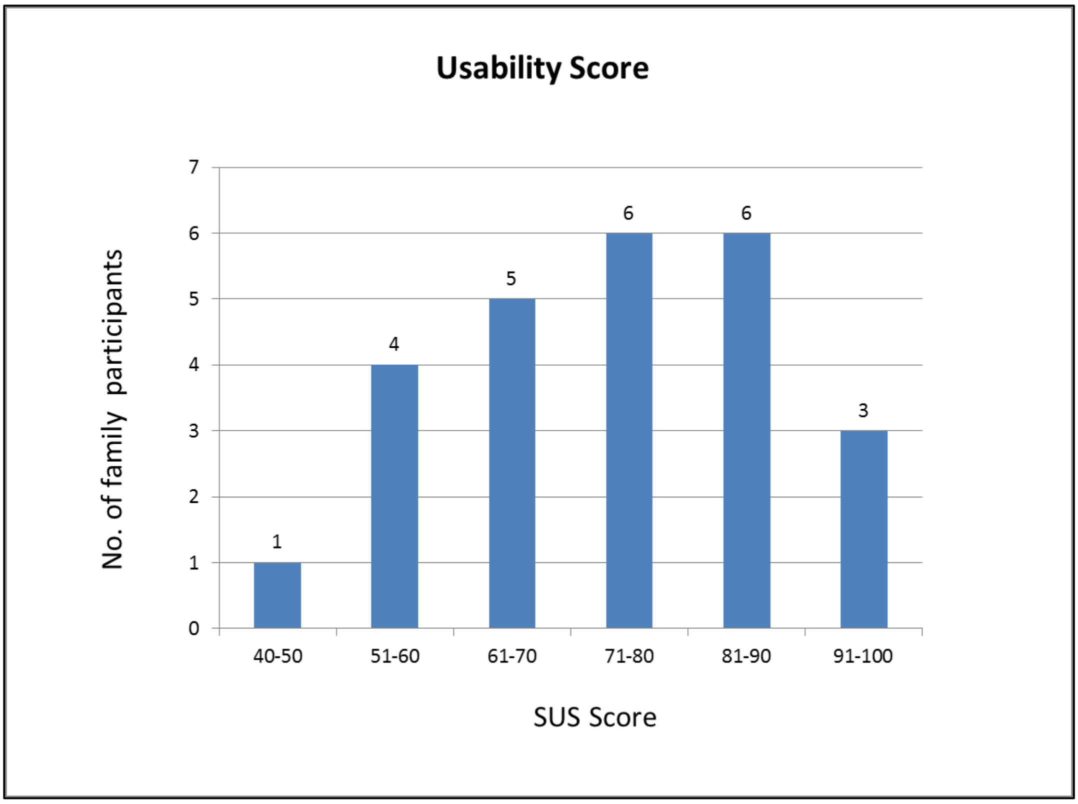



*Figure 6.3 Number of families against SUS score ranges.*

Figure 6.3 presents SUS scores from the family participants in April 2015 with the second version of the NSM mobile app. Three groups of participants gave the app a score above 91, indicating exceptional perceived usability. Additionally, six families rated the SUS score at 81-90 (excellent) and another six groups rated the app with a score of 71-80 (good). Four families gave the app a score of 51-60 and only one family rated the app at 40-50 – thus a total of five families' out of 26 (fewer than 20% of families) perceived usability was below acceptance levels. From the findings, shown in the chart above, it is clear that the majority of families (80%) agreed that this NSM mobile application provides a positive experience for their visit in terms of usability and, therefore, usability problems are unlikely to have influenced the learning experience.

### 6.2.5 Open-ended usability questions

In addition to the SUS usability test of the mobile application, the second part of the usability interview asked the family participants to share their opinions about the impact of using the museum mobile application on their visit through a series of open-ended questions. The same questions were also asked of group C families who used the same version of the app (see evaluation activity concerning the GLOs, section 6.3 below). More generic questions regarding needs and problems which were not specifically about the app were also posed to group B from the same evaluation activity (see section 6.3) who had not used the app, allowing a comparison between needs and problems for app users (groups A and C) and non-users (group B). Responses to the generic usability questions were coded together for all app users, whether in Group A or Group C, and the results are presented below.

The first question regarded the advantages of using the mobile application in the gallery and was posed to groups A and C. Family responses to this question were coded and are summarized in the chart in Figure 6.4.

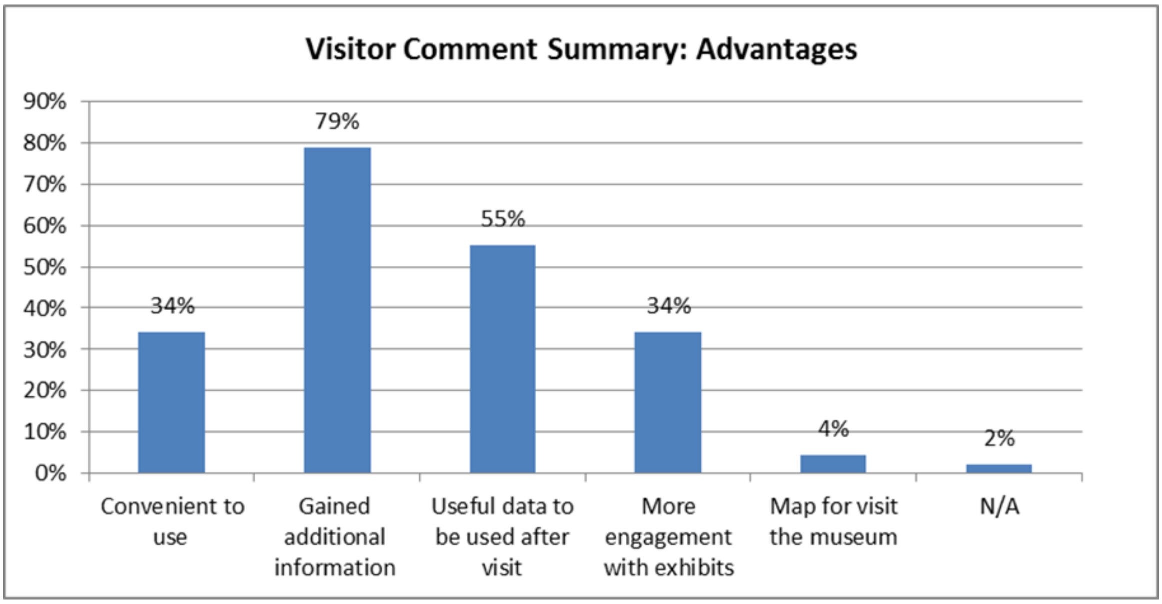



*Figure 6.4 A summary of visitor comments about advantages of using the mobile App in gallery.*

The majority (79 percent) of families who opted to use the mobile application during their visit reported as an advantage of the app that they gained additional information about the scientific content, with instructions how to use the interactive exhibits, and also information about the Science Museum. A third of the family group visitors (34 percent) of the families reported that the mobile application was convenient to use during the gallery visit. Fifty five percent of the family visitors reported that the Science Museum application provides useful data which will be available to access after their visit to the Science Museum. Finally, 34 percent of the families reported that this mobile application supported them to engage more with exhibits in the gallery.

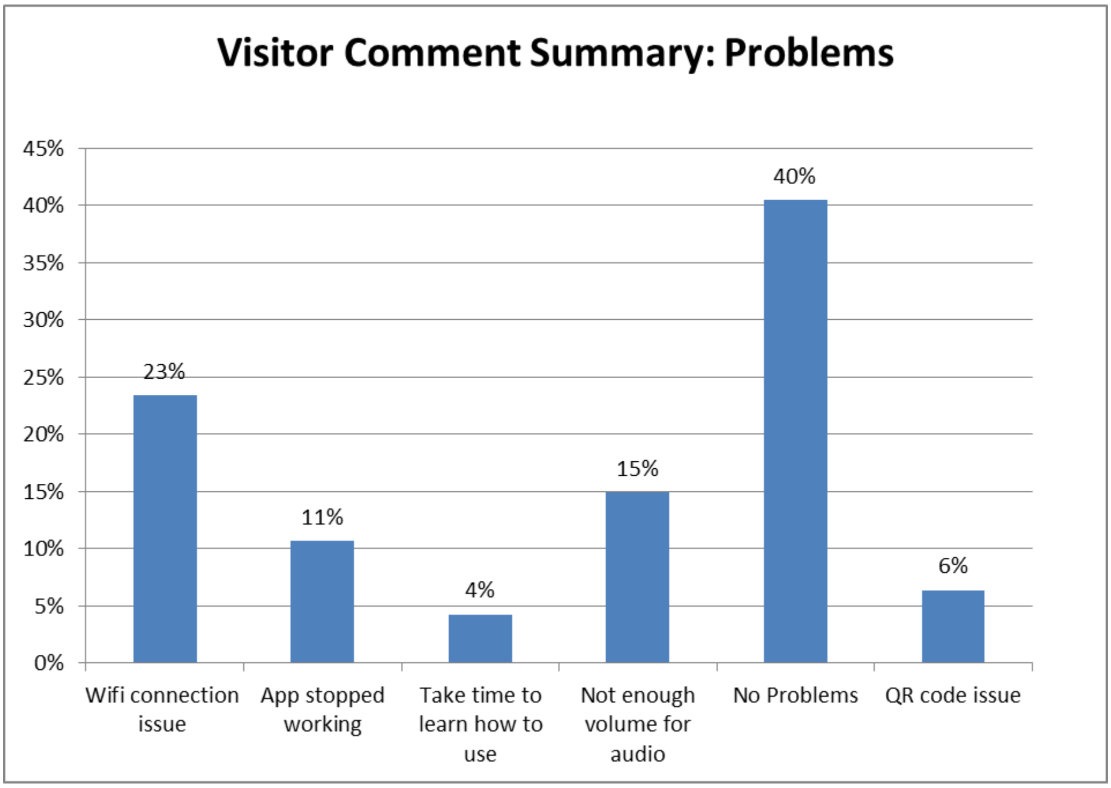



*Figure 6.5 Problems visitors found when using the App.*

The second open-ended question regarded problems that participants faced with the use of the app and was posed to groups A and C. As shown in the graph above, a large proportion of families (40 percent) indicated that there were no problems with the use of the application during their visit. For the rest 60 percent of families, the most reported problems were Wi-Fi connection issues and not high enough volume for the audio mode. The Wi-Fi connection problem may be a result of the limits of access points that cannot serve large crowds of people at the same time. Before the end of April, this issue had been resolved by the NSM's IT unit after receiving this feedback from the researcher. However, it is something that should be taken note of and, to ensure happy users, the working order of the technical infrastructure should be tested and maintained on a regular basis.

The volume of the audio mode in the application became problematic when the users selected to listen to the audio guide from the application (sound mode) on the exhibition floor. This can be a problem when the family members used this mode at an exhibit or location that was surrounded by loud noise from both other visitors and multimedia exhibits. The third floor in particular is loaded full of interactive science exhibits and is regularly crowded. From the researcher's observation, many of the family visitors had to raise the device close to their ear when they wanted to listen to the narrative from the application, particularly on the third floor when there were many visitors around. Sometimes, a visitor would bring other members of their group somewhere quieter to listen to the application together; other times to solve the problem, the visitor who was using the mobile device had to convey the message to other members when surrounded by very loud noises in the Science Museum. This suggests that the choice of media for different parts of the mobile app needs to be informed by the location where that part of the app is going to be used.

11 percent of the family visitors had a problem where the application stopped working during the gallery tour. This problem challenged the application development team and, after a series of diagnostic tests, the bug was found and the application was updated and fixed.

Four percent of families reported problems with the time it takes to learn to use this application. It is unclear whether the learnability issues concerned the interface of the app itself or the use of QR codes, as 6 percent of families reported that these were failing. However, the low frequency with which this problem was reported indicates that this mobile application is generally easy to use for the majority of family visitors – a finding that is corroborated by the SUS evaluation findings presented earlier.

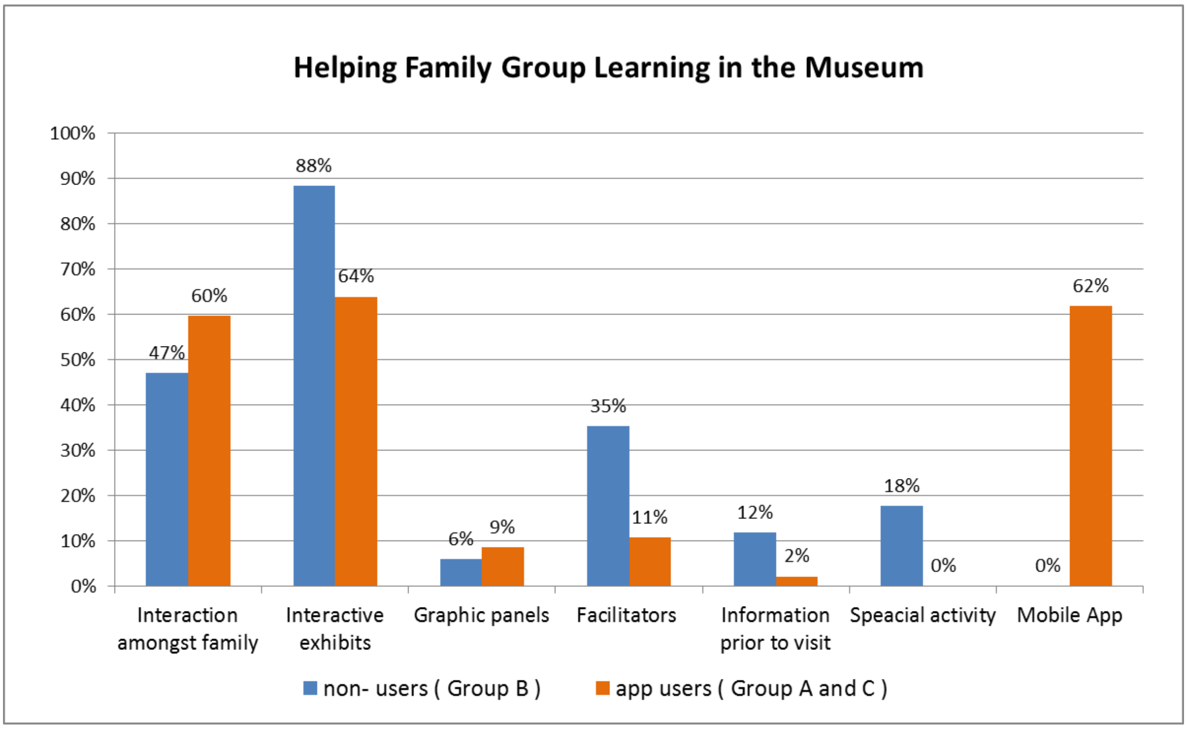



*Figure 6.6 Family App users' (groups A and C) and non-users' (group B) opinions about what can assist family learning with scientific information in the Science Museum.*

The third open-ended question sought to gather participant opinions about what they believed had helped with their family learning in the museum environment. This question was posed to group A and C (users) and B (non-users). As shown in Figure 6.6, the family visitors who did not use the mobile application (i.e. the group B), are more likely to believe that what assisted their family learning in the Science Museum were the interactive exhibits (reported highest at 88%), the interactions amongst family members (reported at 47%), and the museum facilitators (reported at 35%). The app users on the other hand were more likely to report the interactive exhibits, the mobile application, and the interactions amongst family members as factors that assisted family science learning in the museum (at a percentage of 64%, 62%, and 60% respectively).

Clearly, learning interactions are highly valued by both app users and non-users: interactions with the exhibits, with each other, with the app, with museum facilitators.

Interestingly museum facilitators are less likely to be reported by app users as assisting family learning, while the app rises for this group to the same levels of appreciation as interactive exhibits and family interactions.

These findings indicate that family visitors who opted to use the mobile application did not seek learning support from Science Museum staff during their visits - see also findings from the final open-ended question below, which indicates that only 9 percent of families who used the app thought that more facilitators are needed in the gallery. It appears then that the app provision can reduce the strain on museum staff to provide in-gallery support to visitors, thus freeing human resources that can be used by the museum in other ways.

Reading text panels was reported by 6% of non-app users and 9% of app users as a learning aid. As will be seen in the analysis of the observational data in a later section of this chapter, families who used the app were in fact observed to read the text panels more often than non-app users. There seems to be a synergistic relationship between the app and the text panels, as use of the app seems to heighten both the use of the text panels and their appreciation as learning aids.

The figure above also demonstrates that families who did not use the app reported special museum programmes and activities as aids of family science learning science in the Museum, while none of the families who used the app reported this as an aid. It is possible that the app users spend more time using the mobile application and interacting with the exhibits, leaving them less time to participate in organised museum activities. This is corroborated by findings from the video-based observations, which suggest that exhibit dwell time for app users is significantly longer than for non-users (see video findings section later in this Chapter). An alternative explanation of this is that families who were planning to participate in museum programmes and activities during their visit declined to participate in the study. Unfortunately no data is available for non-participants, therefore it is not possible to assess the plausibility of this explanation.

Lastly, the graph shows that 12% of families who were not using the application reported that information that they had learned about the museum prior to their visit assisted with their learning; for app users this percentage was much lower (2%). It is possible that the families who used the application believed that the mobile application allowed them to access information about the museum easily from their mobile devices at any time, everywhere. Therefore, even if they had accessed such information prior to the visit, it was not perceived as distinctive enough to report as a learning aid.

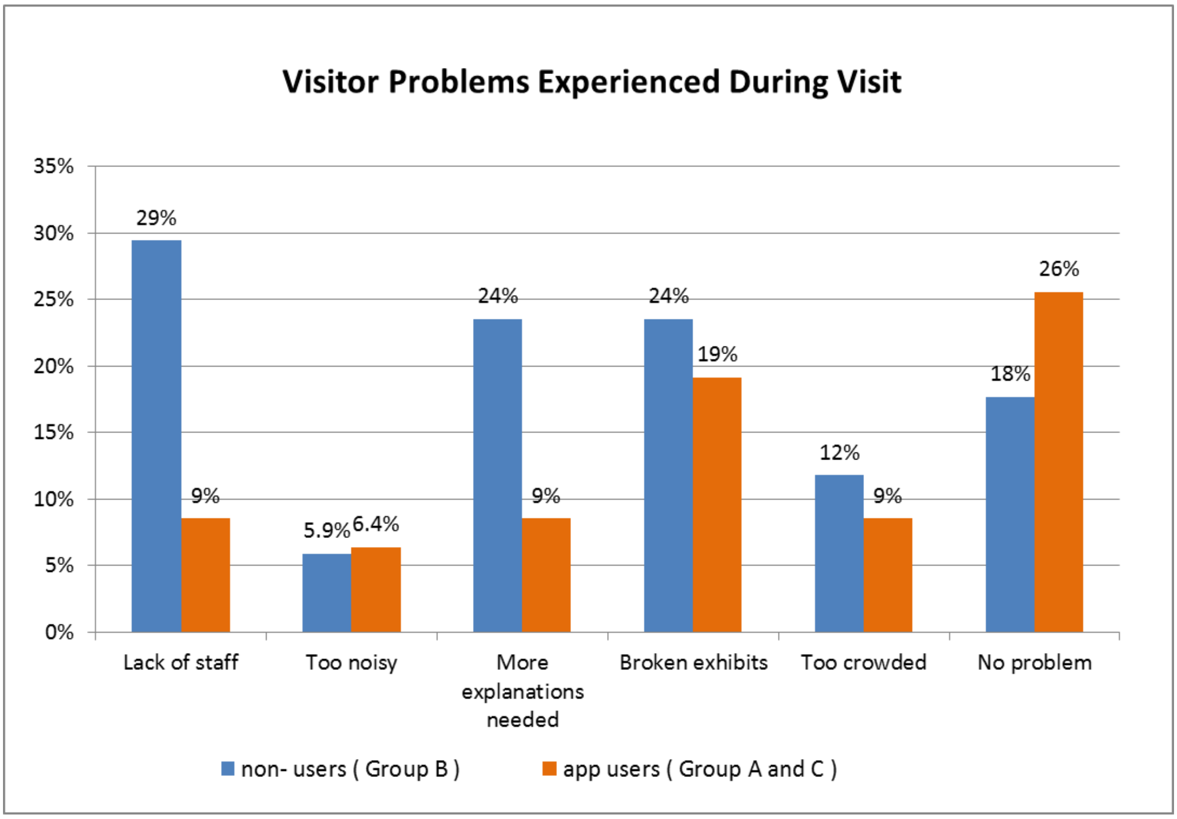



*Figure 6.7 A graph showing the problems App users (groups A and C) and non-users (group B) had with their experience at the Science Museum.*

The fourth open-ended question concerned the general problems that families had during their visits, and was asked to all families in groups A and C (users) and B (non-users) group B. According to Figure 6.7, the most commonly reported general problems by the non-user families were related to the lack of staff to facilitate learning at the exhibition (at 29%), the lack of information or explanations in general (at 24%), and broken interactive exhibits that they could not interact with (at 24%). The graph shows that there was a large difference between app users and non-users regarding the lack of staff (9% versus 29%) and lack of information/explanations (9% versus 24%). This supports the findings from the question discussed previously regarding perceptions of facilitators as aiding learning, and further supports the view that the app is filling in gaps left from the lack of staff and other in-gallery interpretation.

High noise levels and crowded exhibits were perceived as problematic by both app users and non-users. These problems are inter-linked, as large crowds of visitors around an exhibit contribute to increased noise levels on the exhibition floor. High noise levels in particular can be problematic for app users when accessing app audio, which as discussed earlier can be hard to access in a noisy environment. However, the relatively low percentage of app users who explicitly reported this as a problem (6.4%) suggests that, overall, this issue did not affect perceived usability too much.

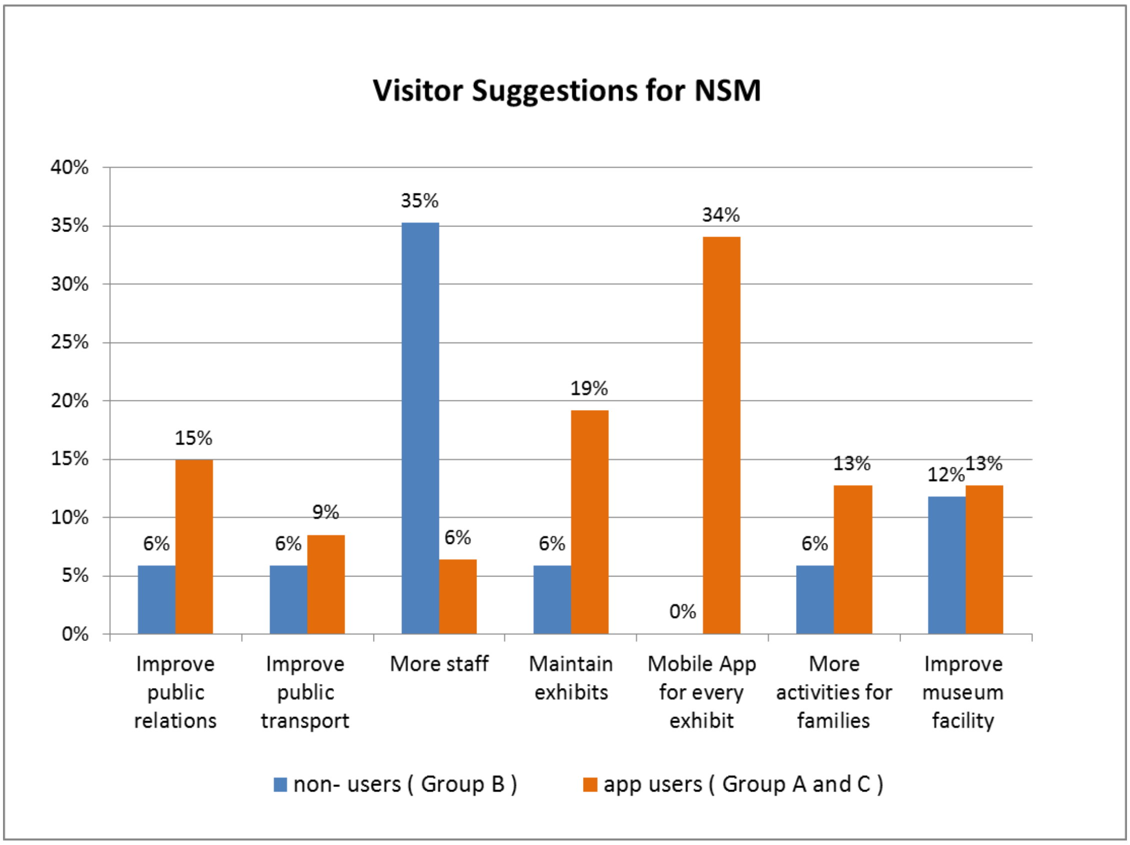



*Figure 6.8 Additional suggestions to improve visitor services of NSM by app users (groups A and C) and non-users (group B).*

The fifth and final open-ended question asked participants to make suggestions concerning improvements in the Science Museum's visitor services for supporting and enhancing family learning. The graph above demonstrates the results of the coded answers received from family participants in groups A, B and C. 35 percent of families who did not use the app wanted more staff facilitators to be available at the exhibition floors. This seems to be of least concern to app users (6%), who instead are placing more importance on extending the app to cover every exhibit in the museum (34%). This supports findings reported earlier in this section that app users are more likely to report the app rather than museum facilitators as a learning aid, therefore wider availability of the app across the museum is more important for app users than wider availability of facilitators.

Better maintenance of the interactive exhibits was reported as an area for improvement by 6% of non-users and 19% of the app users. This suggests that the app does not overshadow the interactive exhibits, as they remain an area of priority for app users. Broken exhibits were reported as a problem by 19% of app users, and the same percentage of them recommended exhibit maintenance as an area for improvement for the museum. Interestingly, while 24% of non-users reported broken exhibits as a problem, only 6% of them identified exhibit maintenance as an area for improvement. This might be because of the greater reliance that non-users seem to have had on museum facilitators to support their learning: interactions with museum facilitators may have compensated for broken exhibits to an extent that interactions with the app could not match. The flexibility of the human facilitator to address topical visitor concerns and needs is not matched by the mobile app. On the contrary, if the mobile app is designed to be used alongside the interactive exhibits, use of the app places more emphasis on exhibits that are in good working order and are maintained regularly.

Other areas for improvement that were identified by both app users and non-users included a wider offer of family activities in the museum; improving public relations through better advertising of exhibitions and activities as well as featuring scientific information and stories on the museum website and other media; improving museum facilities such as restaurants, souvenir and other shops as well as toilets; and improving access through public transportation as the museum is located at a considerable distance from the main road.

### 6.2.6 Summary of usability findings

This part of the summative evaluation aimed to evaluate the usability of the Science Museum's mobile application which was designed based on the needs and problems highlighted in the family learning needs analysis presented in Chapter 4. This research applied the System Usability Score (SUS) method to assess the usability of the App with family participants on-site the Science Museum. The overall SUS score shows that this specially designed mobile application, with a SUS score of 73.75 out of 100, is perceived by users as acceptable in terms of usability. Responses to open-ended questions indicate that, overall, the family App users provide positive feedback after using the NSM mobile application. However, some technical problems while using the application in the gallery were highlighted, included the need to make improvements and regularly monitor the performance of the WiFi connection.

Overall this usability evaluation paints a positive picture of the effectiveness and usefulness of the developed application, emphasizing the importance of interactions for science learning in the museum and the potential for mobile family learning tools that work in synergy with other interpretation methods.

A closer look at learning impacts is necessary, however, in order to understand the extent to and ways in which the app enhanced family learning. The following section presents the next stage of the summative evaluation, which was based on the Generic Learning Outcomes (GLOs) framework as a tool for evaluating family learning in the science museum.

## 6.3 Evaluation of Family Learning Outcomes

### 6.3.1 Introduction

This section presents the second part of the findings from the summative evaluation of this research, which are based on in-depth interviews with family participants and focus on learning outcomes. Data collection for this part of the research was based on pre- and post-visit interviews with family groups in the case study science museum as well as children's drawing as a variation of Personal Meaning Mapping (Falk, Moussouri & Coulson, 1998). This part of the evaluation was designed to collect data from two groups of family participants: *Group B*, which included family participants who visited the science museum gallery without using the mobile application; and *Group C*, which included family participants who visited the science museum and used the mobile application as an additional learning tool for their visit (see Table 6.1 earlier in this chapter). Families in these two groups were interviewed following the same questions and protocols before and after their visit to the exhibition, to enable group comparisons. In addition, the research was designed to collect data from approximately the same number of participants from the two groups. In total seventeen family groups were recruited to group B and twenty-one family groups to the group C. As with the usability participant group discussed in the previous section, families in these two groups were selected randomly by approaching the first family group to enter the museum after the post-visit interview of the last recruited group was completed. All consenting families were included in the research. Families in group B were recruited in the weekend of 18 and 19 April 2015, while families in group C were recruited the following weekend, on 25 and 26 April 2015.

The graph below shows the participating families' prior visitation patterns to the National Science Museum. The distribution to first-time visitors, occasional visitors and frequent visitors was similar for families in the two groups. It should be noted that 'occasional visitors' denoted families who had visited the museum a couple of times over the past few years, while 'frequent visitors' denoted families who had visited the museum more than three times in the past few years (the terms 'frequent visitors' and 'repeat visitors' are used in this section interchangeably). Families in group C were 5 percent more likely to be frequent visitors. This might indicate that frequent visitors were keen to explore new ways of experiencing the museum and therefore more likely to agree to participate in group C, using the app.

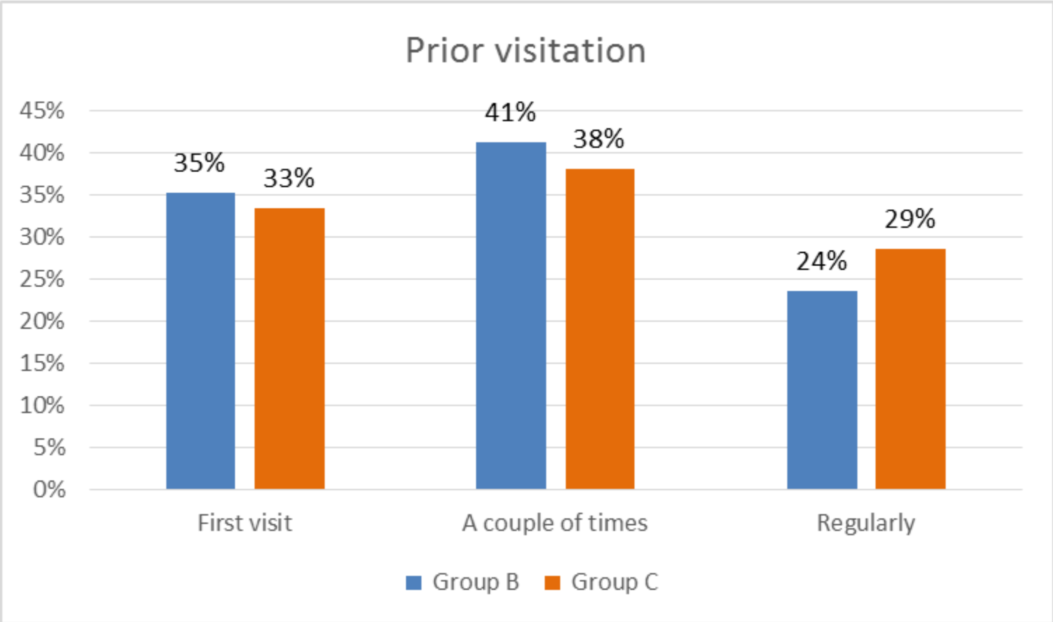



*Figure 6.9 Graph comparing of the prior visitation in groups B and C.*

### 6.3.2 Procedure

The data collection for this evaluation took place on the ground floor of the science museum. Families were approached and invited to participate upon entering the museum. The research aimed to collect data from comparable numbers of family groups in both groups B and C. After a family consented to participate in the study, the pre-visit interview took place with the list of pre-visit questions shown in Appendix 5. The pre-visit questions aimed to elicit general information about the family participants, focusing on their motivations for their visit, as well as information about their prior visits to the Science Museum. The families were also asked questions to elicit their knowledge and understanding of the four selected exhibits: *Lucy, Whisper Dishes, Plasma Ball,* and a camera exhibit displayed in a showcase. In addition, the child(ren) in the family group were asked to draw pictures or write text related to what they found interesting about these exhibits. The pre-visit interview protocols were identical for the two groups (B and C).

After the pre-visit interview, group C participants were introduced to the mobile application, which they were asked to use during the family visit in the museum. The app training lasted approximately 5 minutes and was delivered by the museum facilitator. The training for group C was the same as the training given to usability group A families (see previous section). Both group B and C families were encouraged to visit the four focal exhibits, and both groups could take their time in the museum following their own interests, time availability, etc.

After they finished the gallery tour, participants in both groups were asked to return to the same place to conduct the post visit interviews. Both groups were asked the same set of post-visit interview questions, which focused on the learning impacts of the family museum experience. Children in the family groups were also asked to complete the second part of the drawing-based Personal Meaning Mapping.

### 6.3.3 Data collection and analysis

The pre-and post-visit questions were grouped into three major sections. The first section collected general background information about the family members and the reasons for their visit to the museum. The second section was structured around the Generic Learning Outcomes (GLOs). The last section was about family learning needs and problems (see Appendix 6 for the full list of interview questions). All family interviews were audio recorded and, after the interview, transcribed into a text document. The data collected from interviews was then coded and grouped under key themes that emerged for each question. The following sub-sections present the findings from this analysis.

## 6.4 Finding from the interview

### 6.4.1 Families' visit motivations and agenda

This section presents findings regarding the reasons for visiting of the family groups at the National Science Museum, Thailand. The data discussed here came from seventeen families in group B and twenty-one families in group C. Both groups were asked their reasons for visiting the science museum. Coding of participant responses revealed nine main reasons for visiting: (1) to attend the science museum's programs and activities, (2) to explore particular exhibitions, (3) to entertain their child(ren), (4) to spend a day out with family, (5) to relax, (6) for the parents to learn about science, (7) for the child(ren) to learn about science, (8) to see the museum, and (9) various other reasons.

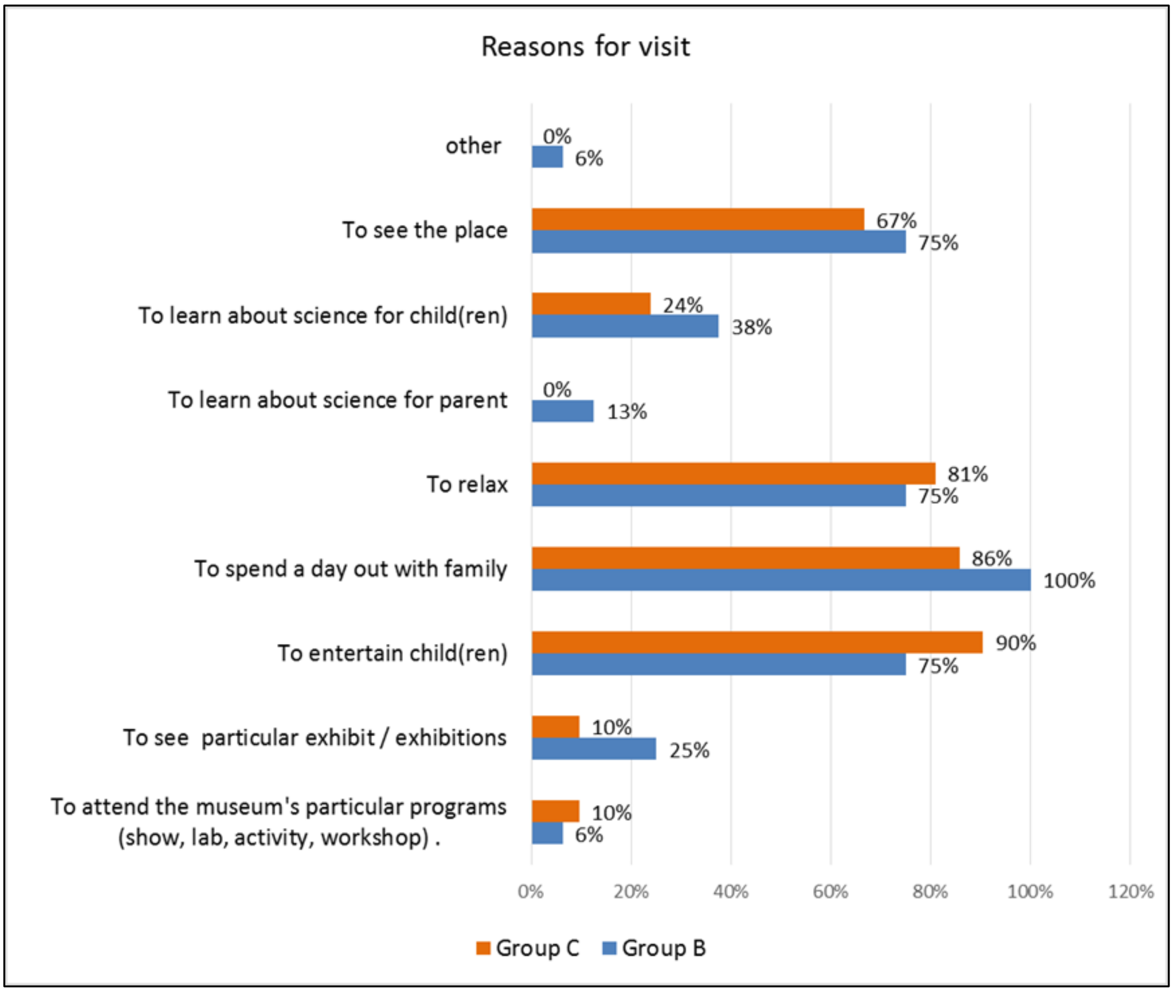



*Figure 6.10 Chart displays reason for visit of the family participants.*

The graph displayed above shows the frequency with which these nine reasons for visiting were cited by families in groups B and C. The four most popular reasons for both family groups that impacted their decision to visit the science museum were: to spend a day out with their family, to entertain their children, to relax, and to see the place. Surprisingly, science learning for either parents or children lags behind these as a reason for visiting. This suggests that families see the science museum as a place where they can spend and enjoy quality time together, while science learning is not a top priority for them. This is also a call for science museum curators to pay attention to the level of language, supporting tools, facilities, programs, activities, and exhibition design so that they not only provide knowledge, but also enjoyment, allowing families to spend time together and fulfil their expectations of the visit to the science museum.

Family visitors in group C cited attending the museum's programs, entertaining their children, and relaxing more frequently than families in group B. It appears that families in group C had a stronger 'entertain and relax' agenda than families in group B. From the graph displayed above, we can see that the majority (90 percent of families) in group C associated their visit with a desire to entertain their children.

Interestingly, parent learning did not feature as a reason for visiting for any of the families in the group C. A quarter of group C families did visit for their children's learning. Families in Group B cited parents' learning and children's learning more often as a reason for visiting than group C families. Combined with the entertainment-focused agenda of group C discussed above, this may indicate that families with a highly entertainment-driven and less learning-driven agenda were more likely to consent to participate in group C and use the app, as the mobile application may be perceived as a tool to entertain the children during the family visit.

### 6.4.2 Findings about Families' Generic Learning Outcomes

#### 6.4.2.1 Changes in knowledge and understanding based on assigned scores

Focusing on the four exhibits, the interview elicited families' knowledge and understanding about generic science concepts and ideas behind these exhibits. The questions about participants' knowledge and understanding of the four exhibits that were asked before and after their visit are shown in table 6.4 below.

Table 6.4 Pre- and post-visit interview questions about families' knowledge and understanding of the four focal exhibits

| Exhibit | Pre-visit questions | Post-visit questions |
|---|---|---|
| 1. Lucy | Have you ever heard about the theory of evolution?<br><br>What do you know about it?<br><br>What do you know about 'Lucy'?<br><br>What is your opinion about 'Lucy' and the theory of evolution? | Have you seen 'Lucy'?<br><br>What do you know about 'Lucy' and the theory of evolution now? |
| 2.Whisper dishes | Can you explain the reflection of sound? | Have you seen and played with the giant dishes in parabolic shape on the third floor? What did you learn from it about the reflection of sound? |
| 3.Plasma ball | What do you know about 'Plasma' or 'a Plasma ball' and what is your opinion about it? | Have you seen and played with the 'Plasma ball'?<br><br>What do you know about 'Plasma' now? |
| 4. Camera | Do you know how the camera was invented and/or how it works? Can you tell me? | Have you seen the camera in the showcase in front of the dark room on the third floor?<br><br>What do you know about its invention and how it works now? |

As the study focused on families who casually visit the museum with diverse interests and varying levels of prior knowledge, it was not meaningful to assess changes in knowledge and understanding through knowledge tests. Instead, this research followed the principles of the Personal Meaning Mapping approach (Falk, Moussouri & Coulson, 1998) and invited participants to describe their current understanding of the scientific concepts and ideas behind the four exhibits through open-ended interview questions. Furthermore, in order to enable younger children to contribute, children in the families were invited to draw or write about the things they learned at the four exhibits.

While this approach overcomes the limitations of knowledge tests, it nevertheless introduces a different challenge: that of quantifying pre- and post-visit levels of knowledge and understanding to make conclusions about positive or negative impacts of the visit. To overcome this, the analysis of the interview data focused on what families said about the exhibits and the extent to which they described and explained the exhibits and the concepts behind them. A marking rubric was devised as follows:

0 = Know nothing about the exhibit

1 = Can describe the exhibit but not explain it

2 = Can describe the exhibit and partially explain it

3 = Can describe and fully explain the exhibit

The table below demonstrates how this marking rubric was applied to the Plasma ball exhibit.

Table 6.5 Answers from family 18 in group C regarding the Plasma ball and scores assigned to these answers using the marking rubric

| | Family answers | Scores |
|---|---|---|
| Pre-visit | It is a glass globe with a sparkly blue lightning inside. | 1 |
| Post-visit | The plasma is the fourth state of matter. Inside the globe, there is an inert gas stimulated by electricity to create the plasma state. The plasma light looks similar to the light of lightning and it contains a lot of positive and negative charge in the ball. | 3 |

Families' pre- and post-visit answers were thus marked for each of the four exhibits, and averaged over for group B and C families separately. The difference in pre- and post-visit mark averages for each group was then calculated for each of the groups. A positive difference in pre- and post-visit averages indicates an overall improvement for the group for the specific exhibit.

Table 6.6 displays the knowledge and understanding scores for all group B and C families for each of the four exhibits, as well as the average score and pre- and post-visit average score differences for each group.

Table 6.6 Knowledge and understanding scores for families in groups B and C for each of the four exhibits

| Group B Family # | Prior visitation | Pre-visit Score | | | | Post-visit Score | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lucy | Dishes | Plasma | Camera | Lucy | Dishes | Plasma | Camera |
| 1 | Regularly | 2 | 3 | 3 | 1 | 2 | 3 | 3 | 1 |
| 2 | Occasionally | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 0 |
| 3 | First time | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 |
| 4 | Regularly | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 5 | Occasionally | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| 6 | Occasionally | 1 | 1 | 1 | 0 | 2 | 1 | 2 | 0 |
| 7 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 8 | Occasionally | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| 9 | Occasionally | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 0 |
| 10 | Occasionally | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 11 | Regularly | 1 | 1 | 1 | 0 | 2 | 1 | 2 | 0 |
| 12 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 13 | Regularly | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| 14 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 15 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 16 | Occasionally | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| 17 | First time | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 |
| Average score group B | | 0.47 | 0.59 | 0.47 | 0.12 | 1.47 | 1.24 | 1.59 | 0.12 |
| Improvement overall group B | | | | | | 1.00 | 0.65 | 1.12 | 0.00 |

| Group C<br>Family # | Prior visitation | Pre-visit Score | | | | Post-visit Score | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lucy | Dishes | Plasma | Camera | Lucy | Dishes | Plasma | Camera |
| 1 | First time | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 |
| 2 | First time | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 |
| 3 | Regularly | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 4 | Regularly | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 5 | First time | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 |
| 6 | Occasionally | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 |
| 7 | Regularly | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 8 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| 9 | Occasionally | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 10 | Regularly | 1 | 1 | 1 | 0 | 2 | 1 | 2 | 0 |
| 11 | First time | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 |
| 12 | Occasionally | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 13 | First time | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 |
| 14 | Occasionally | 1 | 0 | 1 | 0 | 2 | 2 | 1 | 0 |
| 15 | Regularly | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| 16 | Occasionally | 1 | 1 | 1 | 0 | 3 | 3 | 2 | 0 |
| 17 | First time | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 18 | Occasionally | 1 | 1 | 1 | 0 | 2 | 2 | 3 | 0 |
| 19 | Regularly | 1 | 1 | 1 | 0 | 1 | 2 | 2 | 0 |
| 20 | Occasionally | 1 | 0 | 1 | 0 | 1 | 2 | 2 | 0 |
| 21 | Occasionally | 1 | 1 | 1 | 0 | 3 | 2 | 2 | 0 |
| Average score group C | | 0.62 | 0.52 | 0.62 | 0.00 | 1.81 | 1.81 | 1.86 | 0.00 |
| Improvement overall group C | | | | | | 1.19 | 1.29 | 1.24 | 0.00 |

Figure 6.11 below gives a diagrammatic comparison of the improvement in average scores for knowledge and understanding between groups B and C.

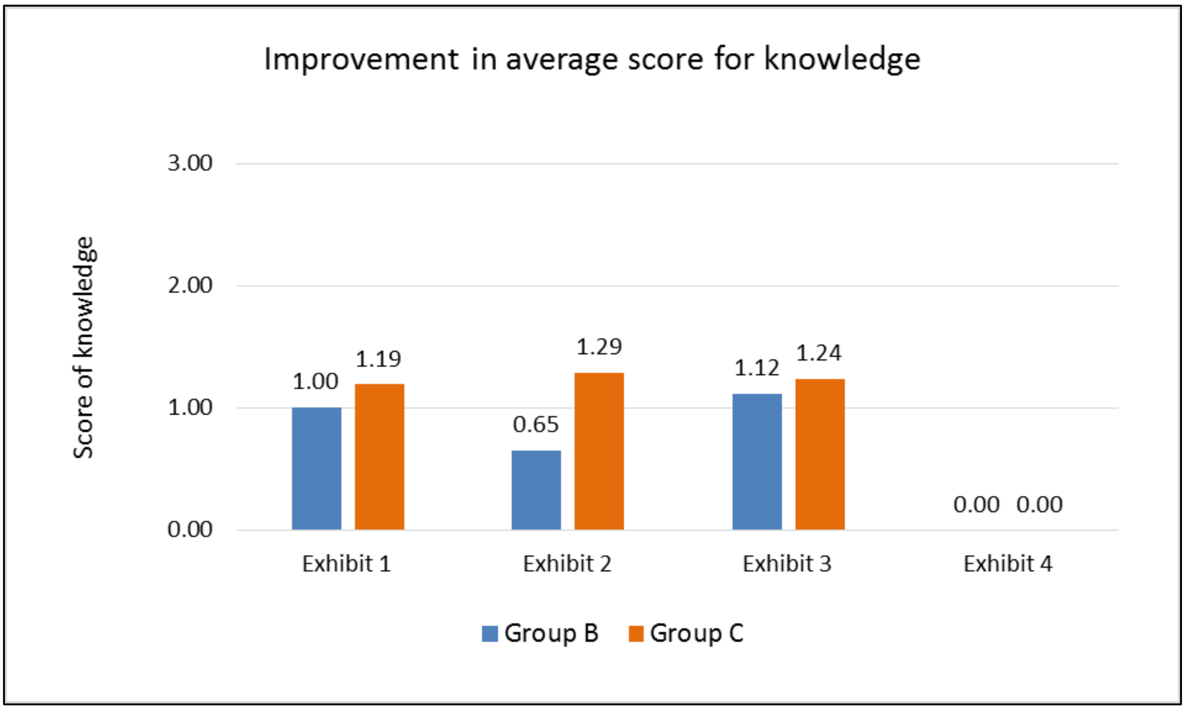



*Figure 6.11 Difference in improvements of average score for knowledge in the selected exhibits (1 – Lucy, 2 – Whisper Dishes, 3 – Plasma ball, 4 - Camera) between groups B and C.*

As shown in the graph, there was improvement in the average scores for both groups B and C for the first three exhibits. Interestingly, there was no change in knowledge and understanding for exhibit 4 (camera) for either group. This could be a result of the location of the exhibit, which sits in a hallway among a wealth of interactive exhibits that are potentially more attractive than the static display case. It is easy to imagine that participating families could have been more interested in the interactive exhibits that provided opportunities for more direct experiences than the objects in the showcase – this is also supported by the findings regarding how visitors value interactivity discussed in the previous section. When asked about this exhibit, families who participated in the study said that they "could not find the exhibit". This suggests a larger issue of exhibit discoverability, which however is outside of the scope of this analysis.

Figure 6.11 above shows that families in group C showed more improvement in their knowledge and understanding of all the other three exhibits than group B families: for Lucy, the average score for group B improved by 1.00 mark, while for group C it improved by 1.19 marks. Group C families who visited Lucy with the app thus improved their knowledge and understanding by 0.19 marks more than group B families. The difference between the two groups' improvement was similar for the Plasma exhibit, at 0.12. However, group C families at the Whisper Dishes exhibit improved their scores by 0.64 marks on average, which is twice the improvement for group B families. One explanation for this lies in the different characteristics of the exhibits, which offer different forms of visitor experience and different levels of interaction.

*Lucy* (Exhibit 1) is a model which the visitor is not allowed to touch or interact with. Available interpretation comprises audio media which visitors can listen to as they approach the exhibit. The mobile application provides additional stories and images of the actual discovery of Lucy's skeleton. The *Whisper Dishes* (Exhibit 2) requires visitors to actively experiment with the exhibit together in order to hear each other's sounds. The mobile application then provides a scientific explanation of their experiment. *Plasma* (Exhibit 3) is a glass ball, with which participants can play by touching it and observe the reaction, while the app further explains what plasma is and how we can find it in many everyday phenomena, like the candle light or the lightning light. It should be noted that the text panels of the exhibits provide similar information to that provided by the app, however, the app provides shorter explanations with additional examples and media in simpler language, to keep it family friendly.

Compared to Lucy's and the Plasma ball's mobile interpretation, the interpretation of the Whisper Dishes not only complements the information available at the exhibit, but is furthermore inextricably linked with the visitors' interaction with the exhibits. This synergy between the family's interactions with the exhibit and the shorter, simple information available through the app seems to have further enhanced group C families' learning. By contrast, when mobile interpretation simply extends the information available at the exhibit, as is the case with Lucy and the Plasma ball, the improvement in knowledge is not much more than without the app.

#### 6.4.2.2 Improvement of knowledge and understanding, and prior visitation

Further analysis was done on improvements in knowledge and understanding by the families' visitation patterns at the National Science Museum. As can be seen in Figure 6.12 below, improvements in average scores for all exhibits were comparable between families who were visiting for the first-time in groups B and C, with differences in improvements ranging from 0.07 to 0.24 marks.

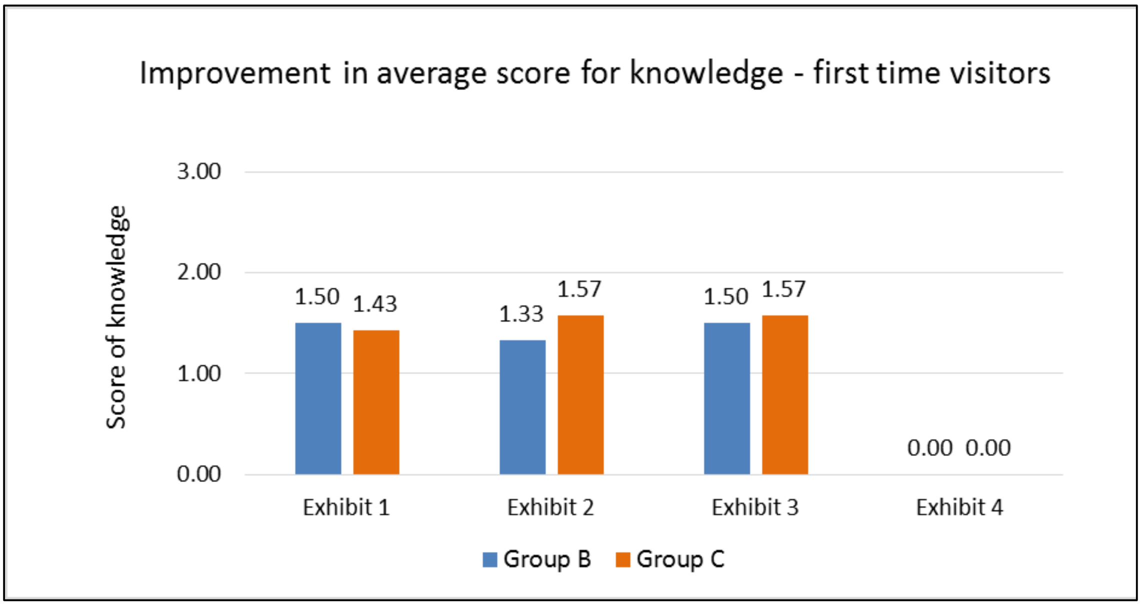



*Figure 6.12 Improvement in average score for knowledge - first time visitors.*

Differences in score improvements were higher for occasional visitors, particularly for exhibit 2 (Whisper Dishes), where group C families who visit the museum occasionally improved their knowledge and understanding by 1.09 marks more than group B families.

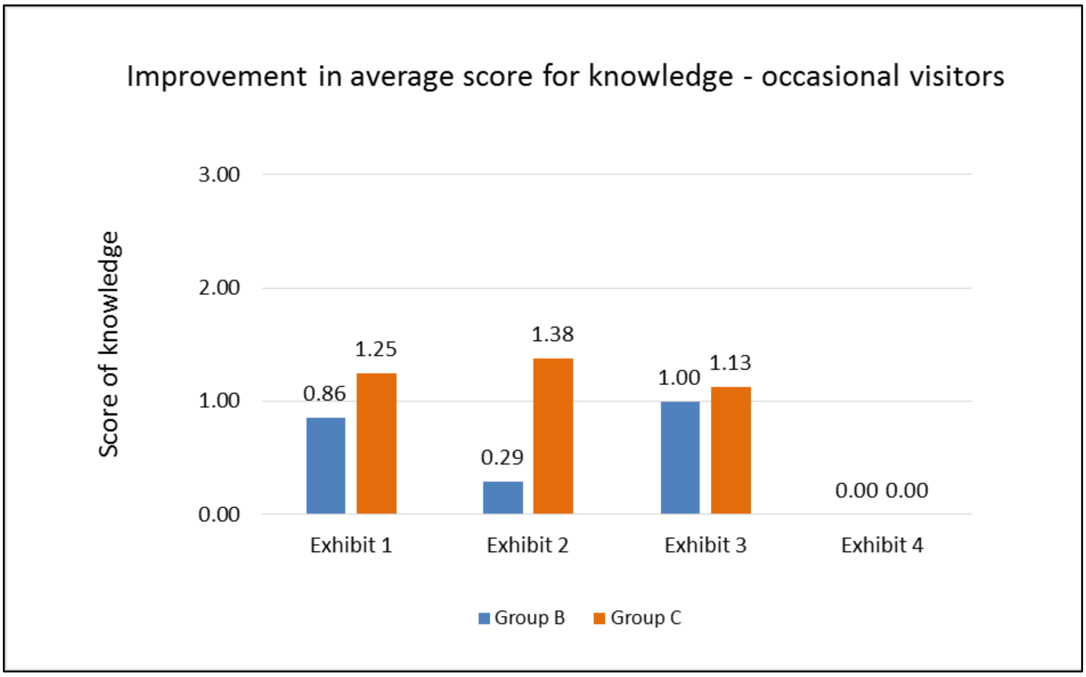



*Figure 6.13 Improvement in average score for knowledge - occasional visitors.*

Similarly, families in group C who regularly visit the science museum improved their scores more than families in group B across all exhibits, with exhibit 2 (Whisper Dishes) showing the highest difference at 0.57 marks.

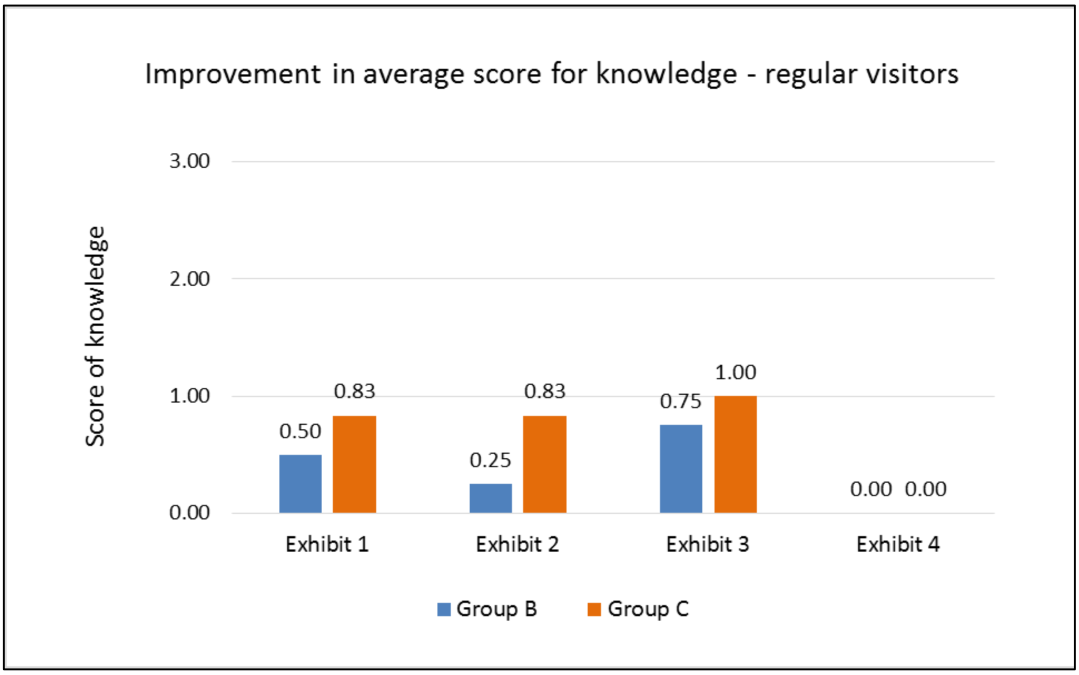



*Figure 6.14 Improvement in average score for knowledge-regular visits.*

These findings indicate that the visit improves the family's knowledge and understanding whether the family uses the app or not. They also indicate, however, that the use of the app accentuates this improvement, particularly for repeat visits. It is possible that, for first-time visitors, there is too much information already to take in: the exhibits themselves and the interactions they afford, the interpretive panels, the newly encountered space of the museum. A mobile app adds an extra layer of information that first-time visitors simply do not have the capacity to absorb. Return visitors, however, who are already familiar with the space, have already encountered the exhibits before and possibly read the text panels, are more open to the additional information that the app makes available. It is also possible that the priority for first time visitors is to gain direct experiences from the physical context of the museum visit rather than interact with the mobile app, particularly so as the app content that has been downloaded onto their device is likely to be available after the visit.

Nevertheless, for families who have been to the museum before the benefits are apparent: using the app results in more gains in knowledge and understanding for all the exhibits. The newly developed content and media of the app expand upon the information already in the panels and the exhibits. Diverse media such as video clips, cartoon animations, and narrated stories combine to provide simple explanations related to real life and enable the families to make connections between the scientific concepts and their experiences. This leads to greater improvements in knowledge and understanding for these participants, thus rendering the mobile application a tool that can support and enhance family science learning in the science museum.

The findings also indicate that knowledge gains for families in group C are higher for the two interactive exhibits, particularly the Whisper Dishes. This is likely a result of the instructions provided within the app regarding how visitors can manipulate and interpret the interactive exhibit, including also extended explanations with examples. These allow family app users to engage with the interactive exhibits confidently and effectively. The combination of simple language, pictures, graphic animations, video clips, and examples related to daily activities seems to have supported group C to increase their understanding and knowledge more than families in group B who did not use the app.

Overall it is clear that use of the app increases improvements in knowledge and understanding for family visitors, particularly those who have visited the museum before.

#### 6.4.2.3 Improvement of skills and prior visitation

Improving existing and developing new skills is the second GLO examined in this study. Both groups B and C were asked questions related to skills they had developed during their museum visit. Data from the interviews were coded and grouped to represent a type of skills. Figure 6.15, Figure 6.16 and Figure 6.17 display the types of skills reported by the participants as gained during their visit.

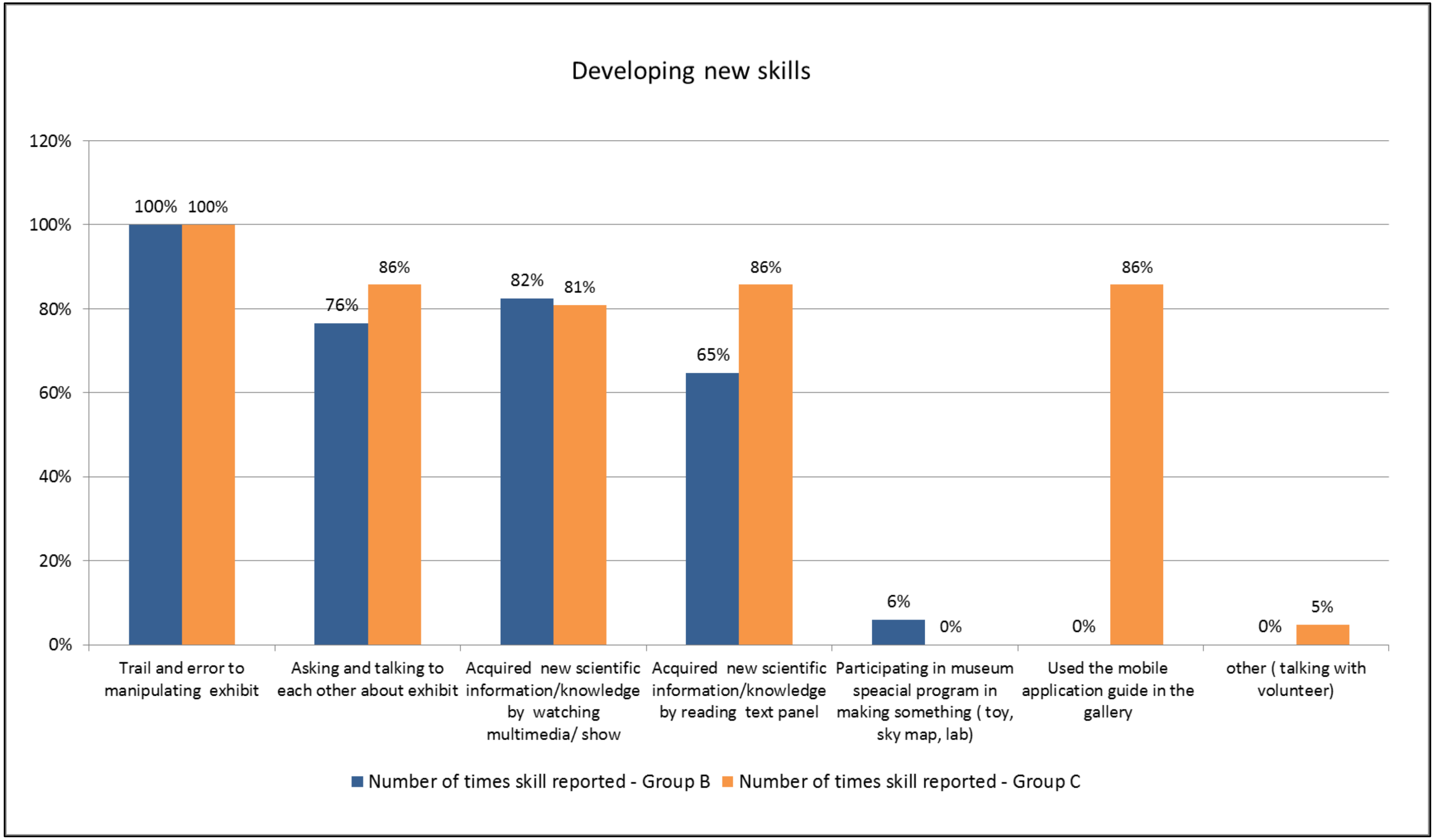



*Figure 6.15 Developing new skills –over all.*

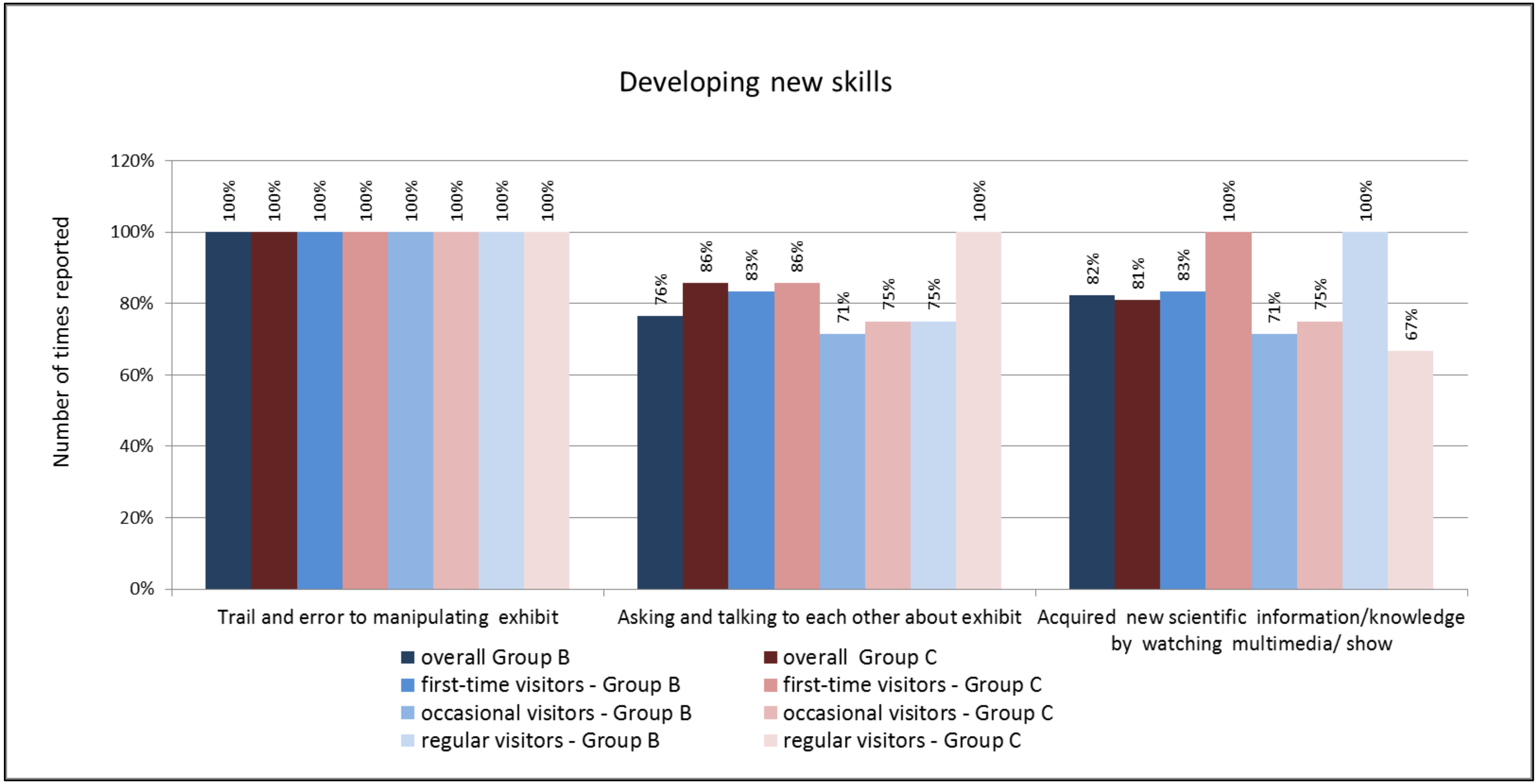



*Figure 6.16 Developing new skills comparing to the prior visitation.*

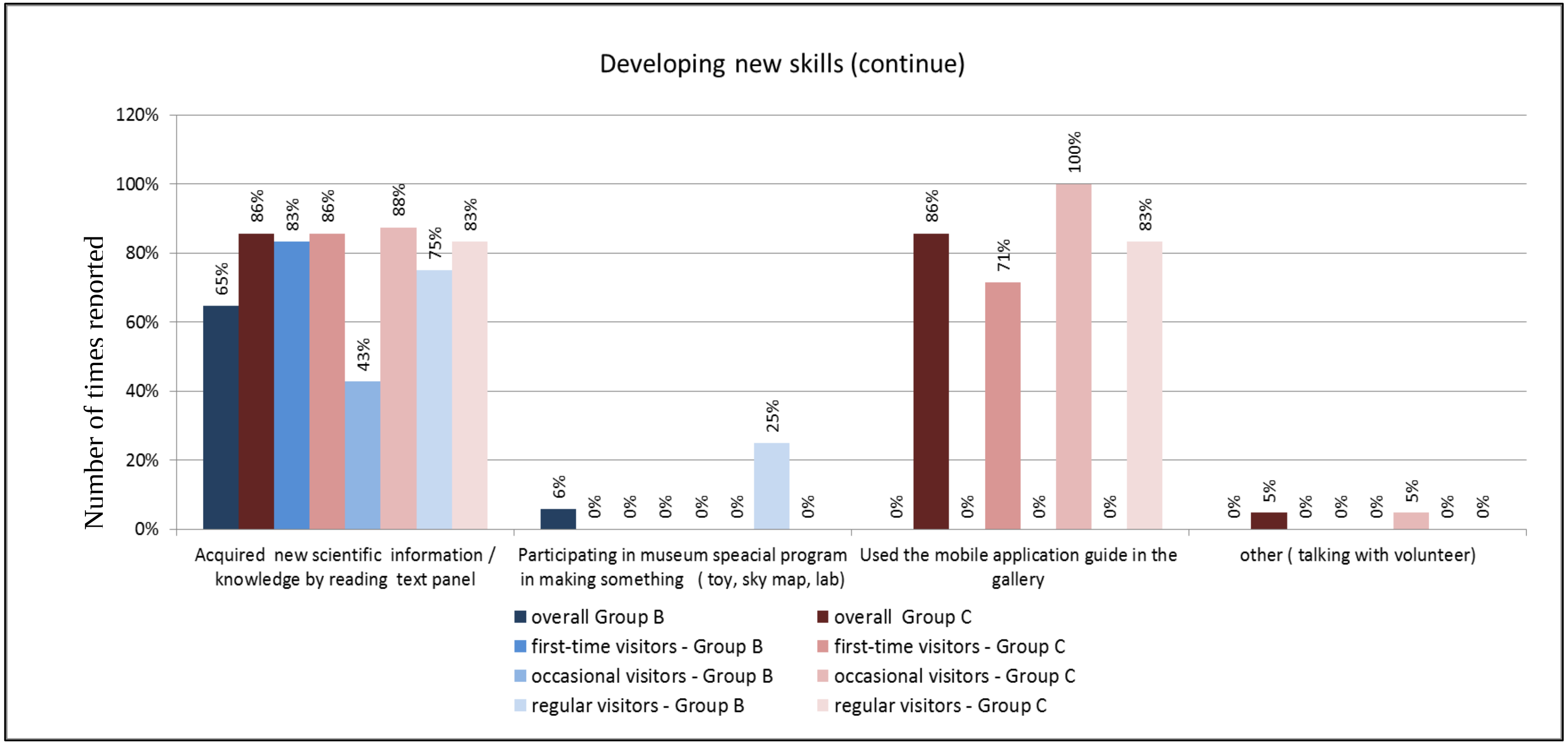



*Figure 6.17 Developing new skills comparing to the prior visitation (continue).*

The findings in Figure 6.15 demonstrate that 100% of families in both groups B and C reported that they had improved their skills in manipulating the museum's interactive exhibits. In addition, science communication skills like asking and talking to each other about the exhibit, were reported by 86% of group C families and 75% of group B families. Both groups indicated that they learned how to develop scientific knowledge by watching multimedia and shows and reading text panels in the museum. The graph shows how the reading of text panels was reported a lot more frequently by group C families (86%) than group B families (65%). This finding aligns with findings from the video-based observations at the plasma ball which are reported in the next section. Only 6% of group B families reported that they learned new skills while participating in the museum's special activities. No group C families reported this type of skill. By contrast, group C families reported the use of mobile technology in the gallery as a new skill they learned (at 86%). Finally, 5% of the group C families reported other skills, such as interacting with museum volunteers in the gallery during their visit.

When looking at a breakdown of the reported skills by pattern of prior visitation from Figure 6.16 and Figure 6.17 it transpires that all the group C families who are regular visitors reported that they benefited from talking with each other about the exhibit, compared with 75% of group B families who visit the museum regularly. Differences between first-time visitors and occasional visitors were much smaller. This might suggest that the app prompted regular visitors to talk more with each other about the exhibit, offering as it was new stimuli through the new material it presented. This conforms with the agenda and motivations of visitors presented in the previous subsection, who want to spend quality time together as a family. The app, therefore, aligns well with the family agenda for the museum visit.

It is also shown that families in both groups perused text panels in similar ways irrespectively of their visitation frequency with the exception of families who visit occasionally, where the families that used the app reported much more text panel use than families in group B. It can be assumed that regular visitors will have seen the panels many times during previous visits, and first time visitors will be reading the panels irrespectively of whether they are using the app or not. Occasional visitors, however, who have only been in the museum a couple of times before, seem to be motivated by the app to inspect the text panels more than occasional visitors who did not use the app.

For the two groups, watching multimedia/shows was overall similar. The app seems to have triggered more watching of multimedia/shows for families in group C who visited for the first time compared with first-time visitors in group B. Families in group B who were regular visitors, however, made much more use of multimedia/shows than group C families. Taken together with the large percentage of regularly visiting families in group B who took part in one of the museum's special activities/programmes, this may indicate that repeat visitors are looking for more unconventional interactions in the museum. The app seems to have fulfilled this need for group C families instead.

#### 6.4.2.4 Changes in Attitudes and Values

Positive changes in attitudes and values regarding both the context and the content of the museum are the third GLO examined in this section. As learning outcomes are impacted by new experiences and information, these can further reinforce the learner's perceptions and feelings. As this research focuses on family science learning experiences within the science museum context, the attitudes and values in this research are framed by and focused on participant attitudes towards science in general and towards the science museum in particular.

Family participants in both groups B and C were asked post-visit questions that sought to capture how their perceptions and opinions about science as a subject and about the science museum might have changed because of the visit. The questions asked were:

- Did the museum visit today change the way you think or feel about a scientific concept or process, or how you view it, if yes how?
- Did the museum visit help you enjoy your family, how?
- Has your visit changed the way you think or feel about the science museum? If yes, in what ways? (Attitudes toward the museum)

- Has your visit changed the way you think or feel about science learning in general, and /or about science learning in your family?
- To what extent and in what ways do you think the visit has made your family think or feel differently about any of the following?
    - Other people/ community
    - Science Learning
    - Museums in general
    - Anything else

These questions were used as prompts for participants to reflect on how their views, perceptions and attitudes had changed through the visit. Participant responses were thus coded into categories of attitudes towards science in general, and towards the science museum in particular. The following subsections discuss these findings.

#### 6.4.2.5 Attitudes towards science

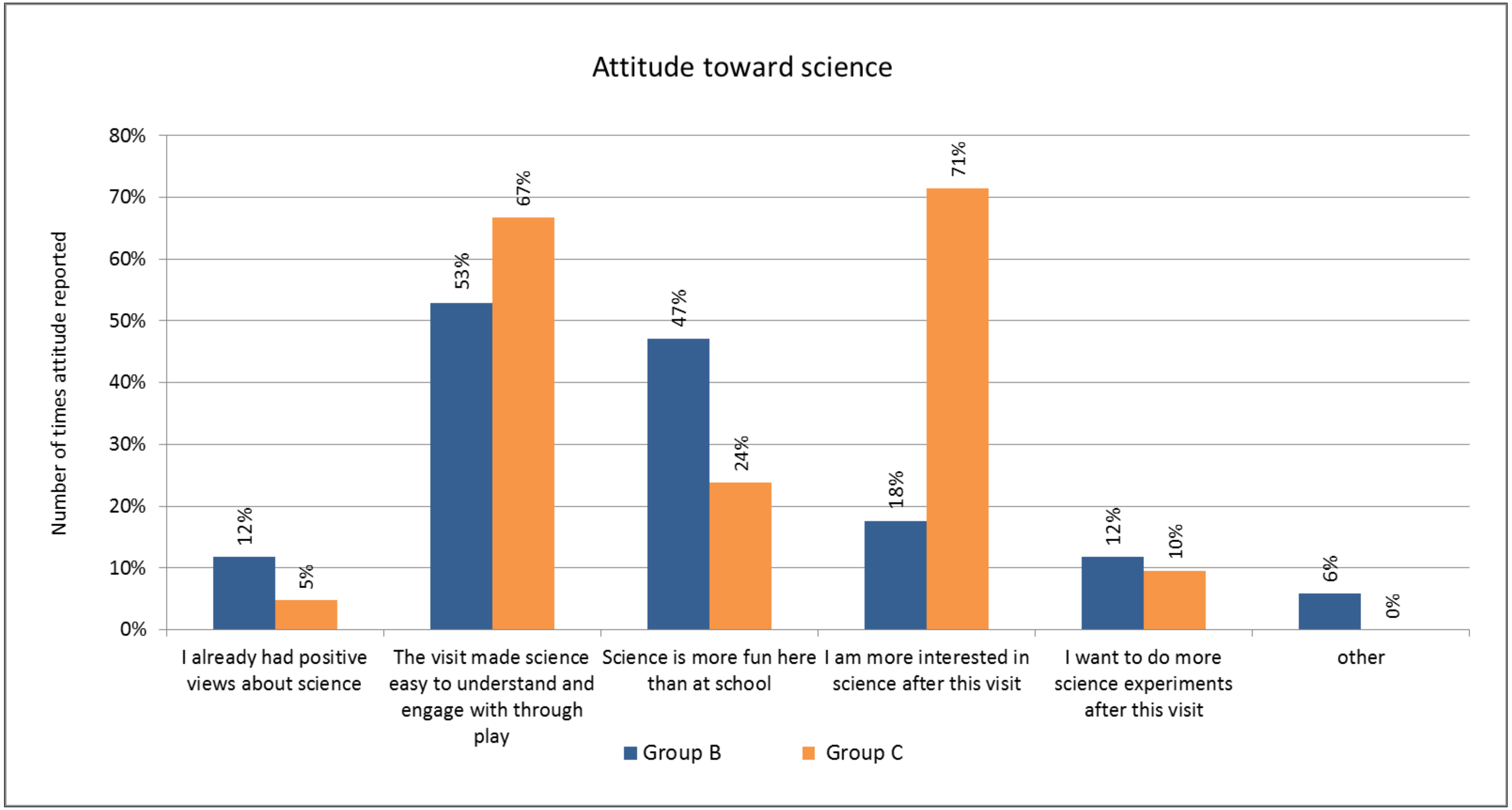



*Figure 6.18 Attitudes and Values toward science-over all.*

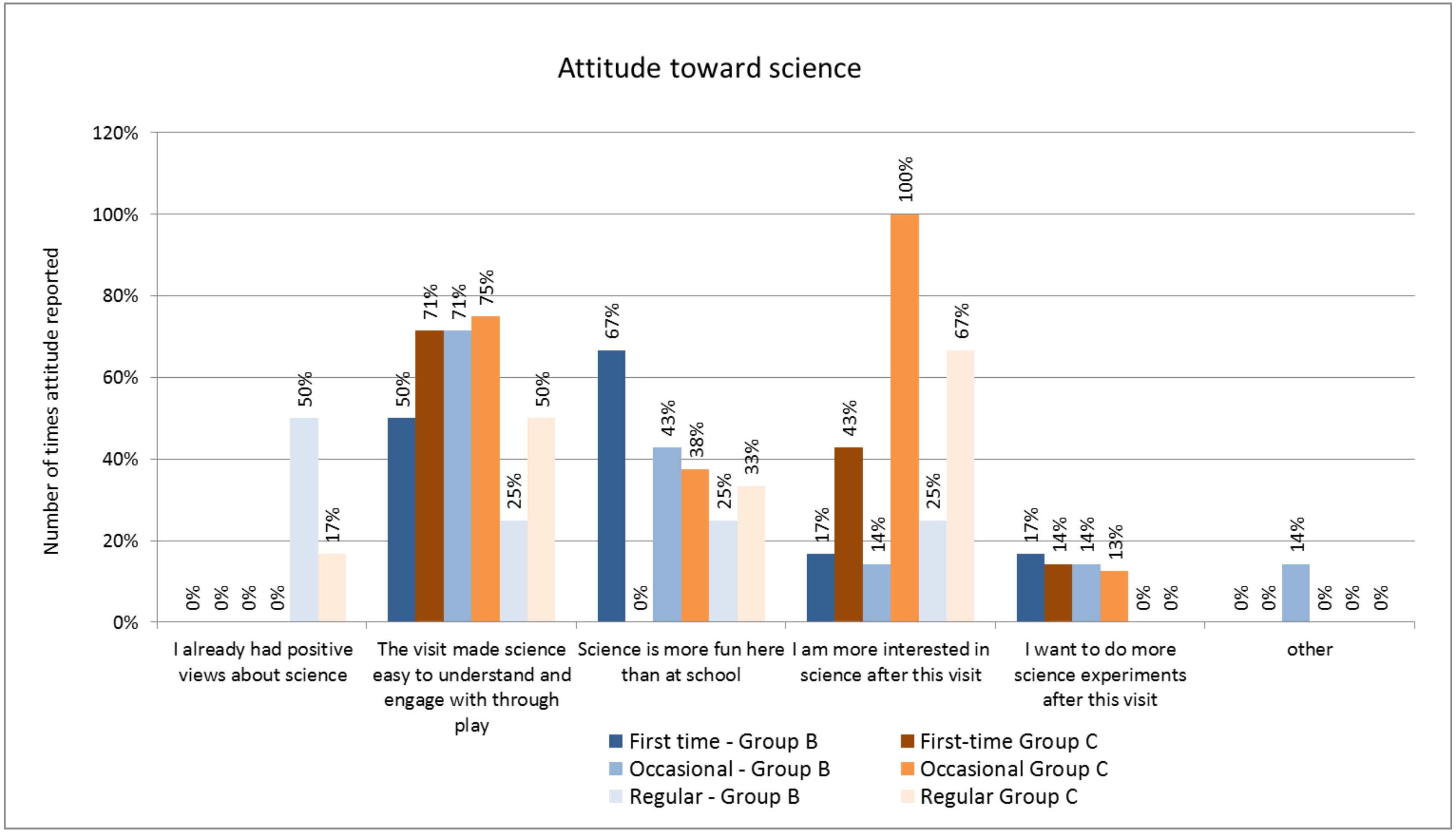



*Figure 6.19 Attitudes and Values toward science comparing to the prior visitation.*

Figure 6.18 and Figure 6.19 show attitudes towards science reported by family visitors after their visit. The broad categories of attitude change reported by groups B and C were similar, and included making science easier to understand and engage with through play; making science more fun than formal science education; increased interest in science; and increased willingness to engage in scientific experimentation. However, these attitudinal changes were not reported uniformly across groups B and C, nor across first-time, occasional and regular visitors.

As can be seen in the graph, group B families were more likely to report that the visit changed their views of science, getting them to view science as a subject that is easier to understand and possible to engage with in a playful way, unlike the non-fun of formal science education. Group B families, however, were less likely to report increased interest in science or increased willingness to engage in scientific experimentation after their visit.

By contrast, group C families were equally highly likely to report changed views of science as a fun, easy to understand subject that can be engaged with through play, and in which they are now more interested in. Group C families too, however, were much less likely to report increased willingness to engage in scientific experimentation.

Interestingly, while 50% of regular visitors in group B said that they already had positive attitudes towards science, only 17% of regular visitors in group C said the same. However, regular visitors in group C were much more likely than their group B counterparts to report positive changes in attitudes towards science after the visit. In this respect the app appears to have had a positive impact for this group in terms of changes in attitudes and values: its use enabled families who visit regularly to engage with the science museum as a playful, fun and cognitively accessible science learning environment. The same was true to an extent with first-time visitors in group C, who did not however report differences between school science and science learning in the museum. As for occasional visitors, responses from group B and C families were comparable, with one notable difference: all group C families who visit the museum occasionally reported increased interest in science as a result of their visit.

Overall, the app seems to have had a positive impact in terms of changes in attitudes towards science, by accentuating the already positive impact of the museum visit itself as evidenced in the data from group B. As with changes in knowledge and understanding, the app's impact is even more prominent for visitors who have been to the museum before, highlighting the need to differentiate between first-time and repeat visits and seeking to further nuance the needs of these two audience groups.

Also notable is the fact that only a few group B and C families reported that the visit led them to develop an interest in experimenting with science concepts. Apparently playing with an exhibit and conducting hands-on observations to understand a phenomenon (like with the plasma ball) is not quite the same as conducting a scientific experiment. The low percentages here match the low percentages of families who said they participated in a hands-on museum programme or activity (see Figure 6.17 above). In addition, the content of the app focused on understanding the concepts behind the exhibits and explaining how the exhibits work, rather than suggesting science experiments or explaining the scientific process. It is clear that, if a larger impact of the science museum visit in this respect is desired, more thought needs to be put in both the museum exhibits and the app.

#### 6.4.2.6 Changes in attitudes towards the Science Museum

As the science museum is the focal institution in this research, it is important to explore the visitors' perceptions of the science museum and how they changed through their visit. Data on this came mainly from responses to question 18 (see questionnaire in Appendix 6), "Has your visit changed the way you think or feel about the science museum? If yes, in what ways?" Participant responses were coded into the categories shown in Figure 6.20 and Figure 6.21, which displays the findings on family attitudes towards the science museum.

Families in group B mentioned on average one positive and one negative thing about the museum. Families in the app user group, mentioned on average three positive and one negative things about the museum. This difference shows an overall positive difference between app user and non-user families' perceptions of the museum.

The family responses in Figure 6.20 and Figure 6.21 below further demonstrate this. Notably, only group C families commented on the value of the museum in the city, highlighting its modern design and how it should act as a model for other museums. Other ‘attitudinal affiliations’ with the museum are shared by both groups. In particular, group C families are almost twice as likely to find the museum a good leisure place for the family and a good informal learning environment for everyone. Group C families are also a third more likely to report general positive feelings towards the museum. In addition, and in accord with the usability data discussed in the previous section, group C families were less likely to report a need for more facilitators in the gallery, demonstrating that perhaps the app assumed the role of learning facilitator. Group C families were also twice as likely as group B families to report broken exhibits as something that impacts their attitudes towards the museum. It is possible that an app that engages visitors with science and with the museum’s interactive exhibits, draws the user’s attention to those exhibits that do not work and which go unnoticed by a larger number of group B families due to lesser engagement.

Finally, overall, comparable numbers of group B and C families reported the physical distance of the museum from the city as a factor that impacts on their perceptions of the museum. Although this issue is beyond the scope of this investigation, it is worth noting as an issue that needs to be taken into account at planning level, and which raises further needs for remote engagement through digital media.

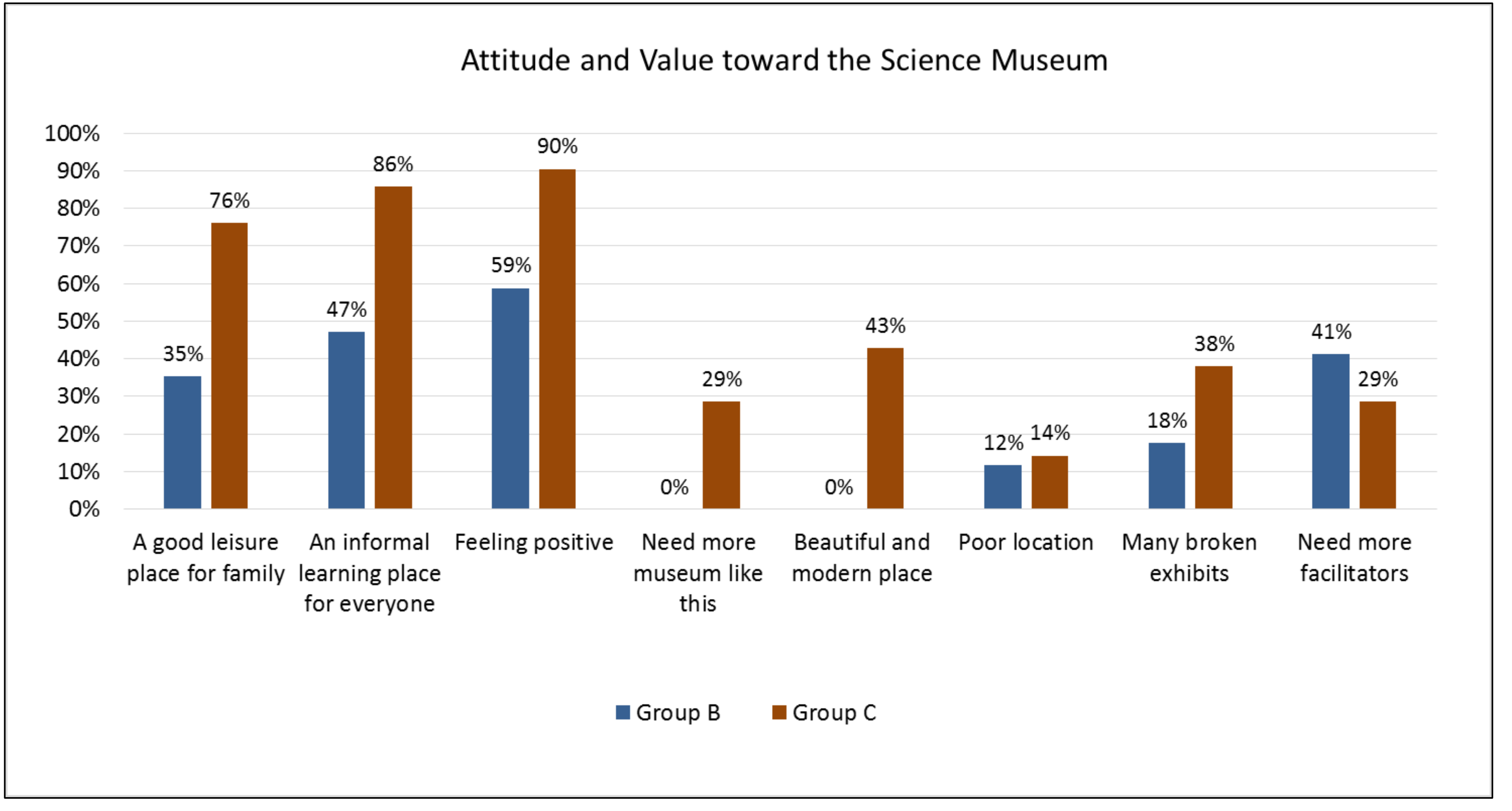



*Figure 6.20 Graph displays Attitude and Value toward the Science Museum –over all.*

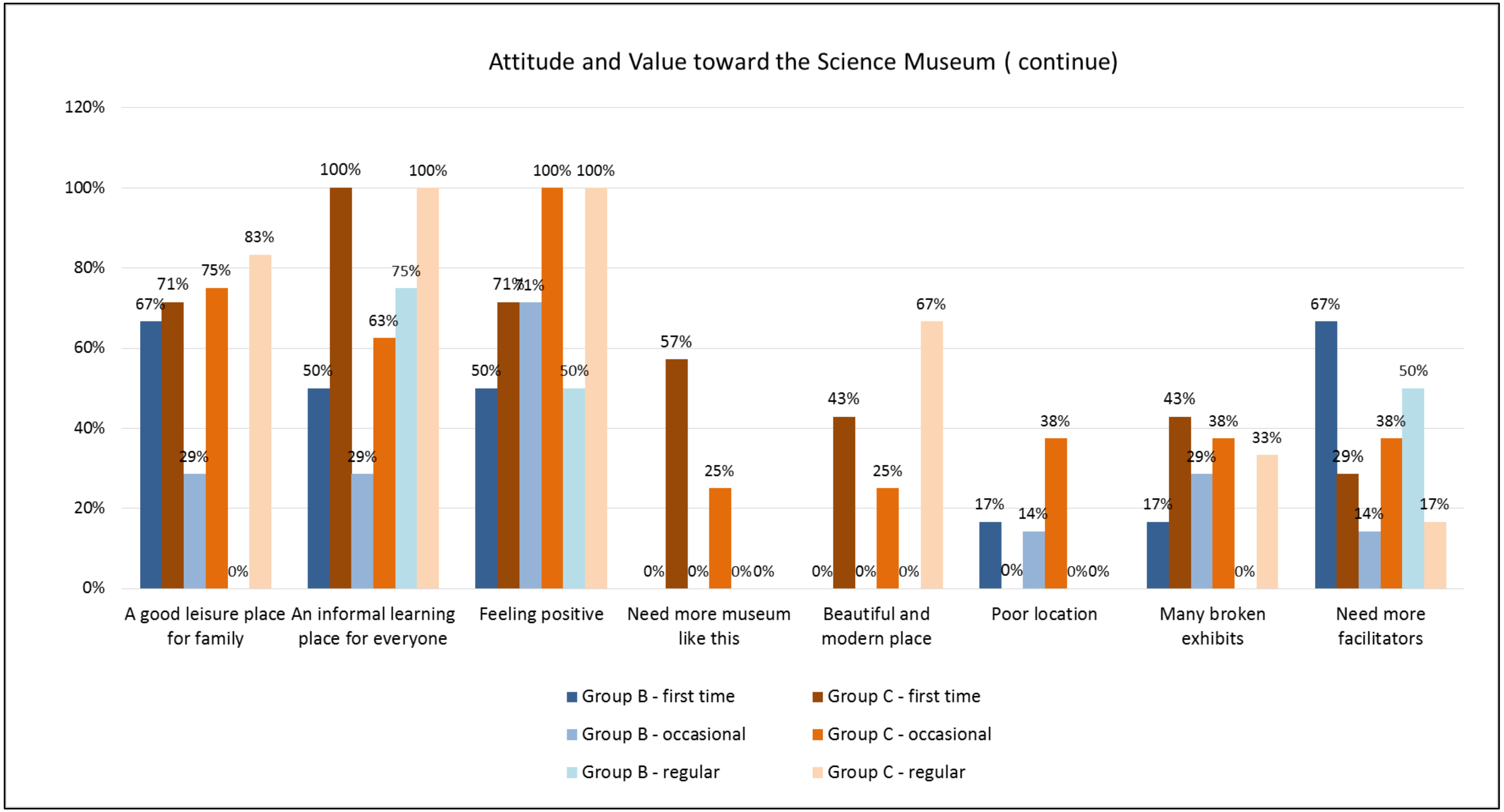



*Figure 6.21 Graph displays Attitude and Value toward the Science Museum comparing to the prior visitation.*

#### 6.4.2.7 Evidence of Enjoyment

The next GLO in focus is ‘enjoyment, inspiration, creativity’. Here we focus in particular on enjoyment, as it is the lack of this that science as an educational subject is often accused of. Families’ responses to the question “what did you particularly enjoy today” were coded and are presented in the graph in Figure 6.22 below.

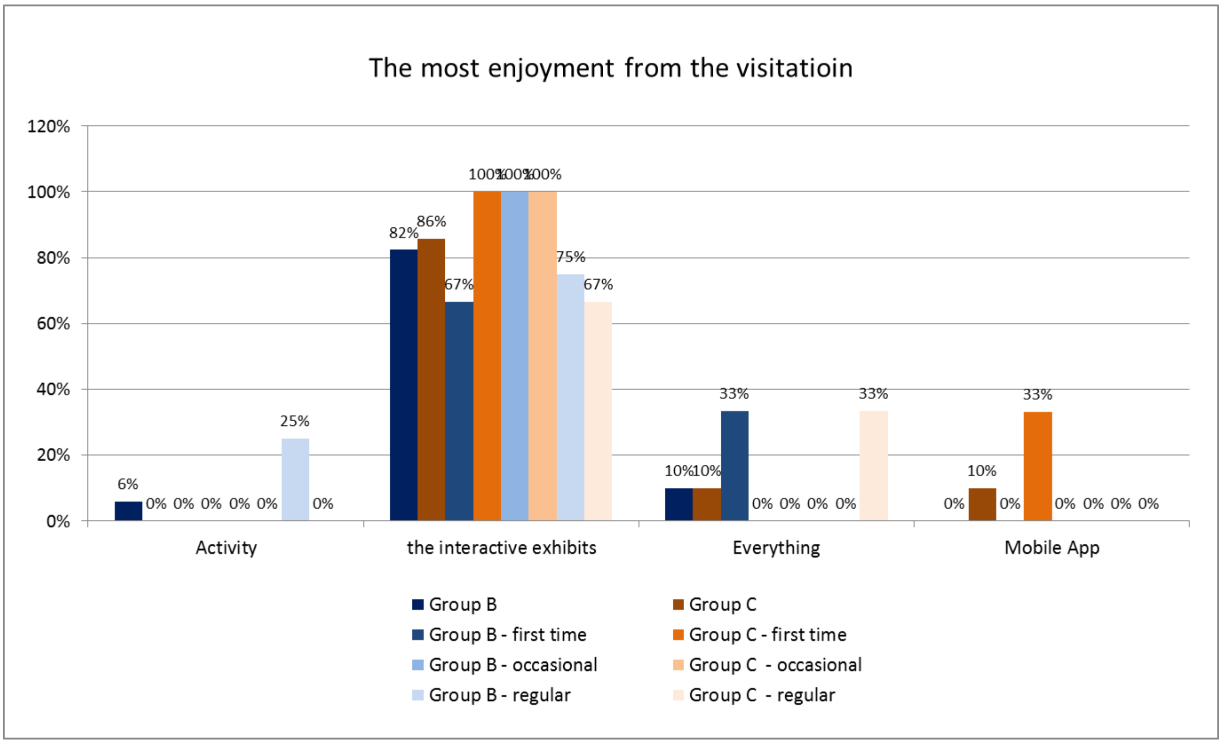



*Figure 6.22 The evidence of enjoyment reported from both group of participant.*

As shown in the figure, both group B and C families were equally likely to say they enjoyed the interactive exhibits. While there were no significant variations between the proportions of occasional and repeat visitors in the two groups who gave this response, the first-time visitors in group C were significantly more likely (100%) than group B first-time visitors (67%) to say they enjoyed the interactive exhibits. It appears that for group B, it is the occasional visitors who enjoy the interactive exhibits, whereas first-time visitors and repeat visitors are less likely to say so – the former perhaps because of inexperience, the latter perhaps because the interactive have lost their novelty factor.

For group C, however, first-time visitors joined occasional visitors to unanimously identify the interactive exhibits as a particularly enjoyable part of the visit. In fact, 33 percent of group C first-time visitors said they particularly enjoyed using the app. It appears then that, for this group, the app had a dual enjoyment impact, being the source of enjoyment itself as well as enabling first-time visitors to enjoy the interactive exhibits.

For a small percentage of respondents in group B, particularly enjoyable were the museum activities they took part in. As seen earlier, group C families do not seem to have taken part in any such activities or programmes; as the app covers exhibits but does not cover other activities or programmes, we cannot comment on the app's impact on this aspect of the visit.

#### 6.4.2.8 Evidence of Action, Behaviour and Progression

The next GLO explored in this study was 'action, behaviour and progression'. This GLO looks at potential transformative impacts of the museum experience: how the visit might inspire visitors to take action related to the topics explored in the museum, or change their behaviour in some ways (Hooper-Greenhill *et al.*, 2003). The interview question in this part ("What, if anything, do you think the young people in your group might want to do as a result of today's visit?") sought evidence of such impacts. A range of future behaviours and actions were reported by group B and C families. Figure 6.23 below summarises the categories that emerged from coding this data and shows percentages of families in each group that included each category in their response.

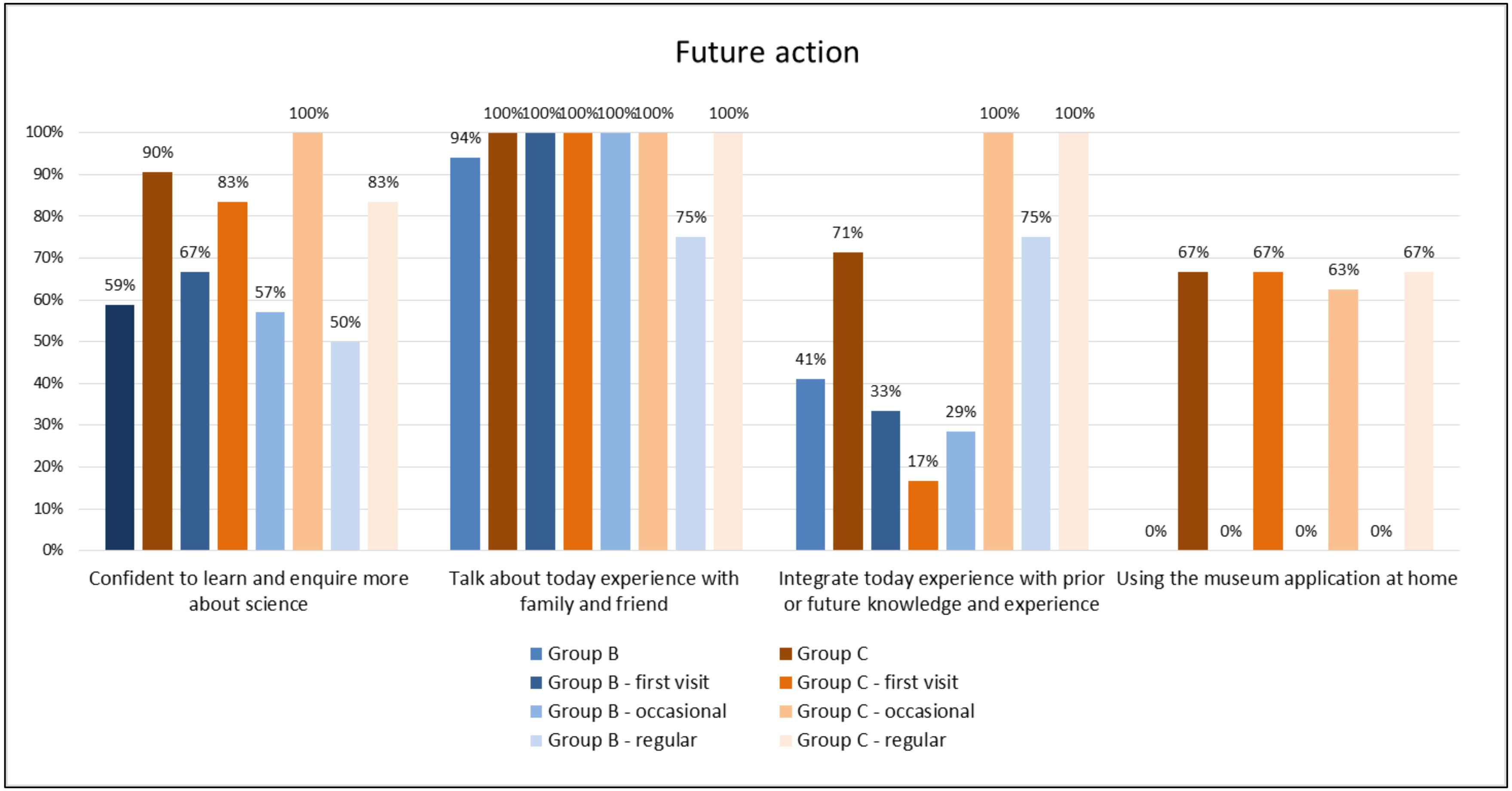



*Figure 6.23 Graph displays Expectation of Future Action.*

As shown in the graph, the vast majority of families in both groups B and C resolved to talk about their visit with friends and family. Interestingly, while repeat visitors in group B are less likely to do so, all repeat visitors in group C resolved to do so, indicating that perhaps the app gave these 'veteran' visitors something new to talk about with their friends and family.

Families in group C were more likely to report that the visit gave them confidence to learn and enquire more about science. It is important to notice that while for group B the likelihood to report this outcome drops from first-time visitors to occasional visitors to regular visitors, for group C this likelihood is much higher and remains uniformly high for visitors of all visit frequencies. It therefore seems that the app brings back the enthusiasm about science that a first visit inspires, while amplifying enthusiasm for the first visit itself.

Families in both groups also said they would be making connections with past and future science learning experiences. As is shown in the graph, all occasional and repeat visitors in group C reported this, compared with 29 percent occasional and 75 percent repeat visitors in group B. However, first time visitors were more likely to report this if they were in group B (33 percent) rather than in group C (17 percent). Clearly, the app did not help as many first-time visitors to appreciate these connections and see how they could act to make them in the future. Nevertheless, a large majority of group C families, including first-time visitors, resolved to use the app again after their visit, thus indicating their intention to construct a follow-on, linked, science learning experience of their own making, while continuing their relationship with the museum after they have left; in a sense, they are taking the museum home with them.

#### 6.4.2.9 Family behaviour in the gallery

As well as the GLO-related data, the pre- and post-visit interviews discussed in the previous section also asked participants to describe what they did in the galleries. The families' self-descriptions of their gallery activity were coded into two major categories: one related to who led the family's visit itinerary, and one related to the more specific activities the family engaged in.

**Who leads the visit?**

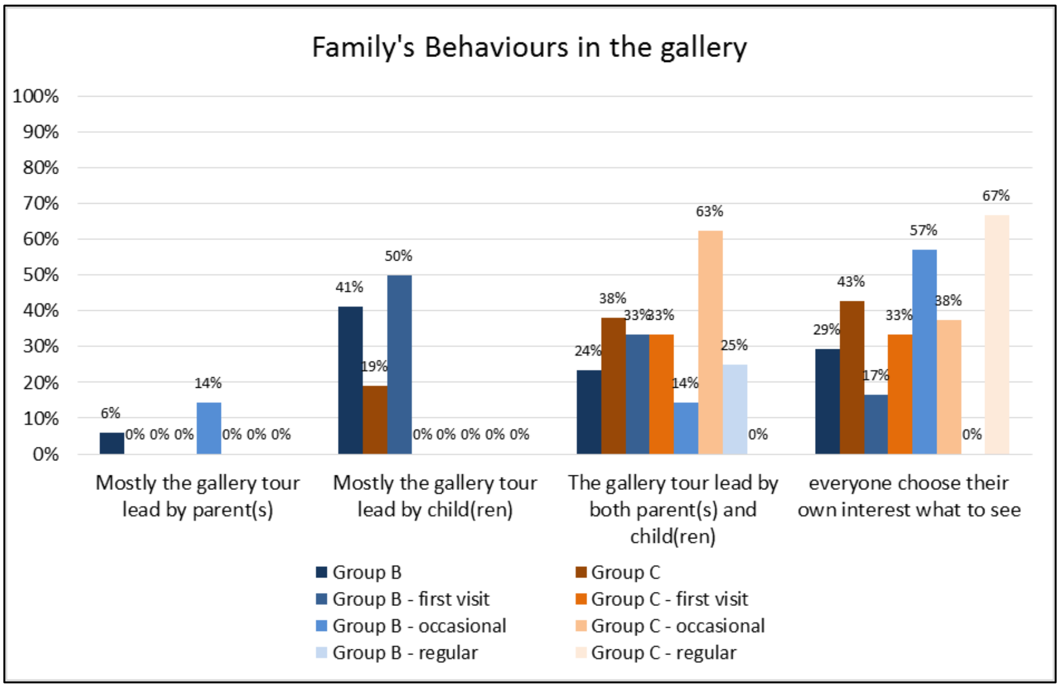



*Figure 6.24 Chart display the action of family during the museum visit.*

The graph in Figure 6.24 displays data related to who was leading the family's itinerary in the museum: the adults, the children, both, or no-one. Only a small percentage of group B families (6 percent) said that it was the parents who were leading the children, while no group C family said so. Children in most family groups have agency in defining the itinerary of the family's visit. This does not mean that children always lead, however. Just over 40 percent group B and under 20 percent group C families said that it was the children who were leading the family group. Children in first-time and repeat visitor families were more likely to lead, in both group B and C. Just under a quarter of group B families, and over a third of group C families, said that adults and children were both leading the group, taking a more democratic approach to the construction of their itinerary. Finally, just under a third of group B families, and nearly half group C families, said that they took a looser approach to the construction of their itinerary, allowing everyone to follow their interests and curiosity. Pioneers in this approach were group C's repeat visitors, 67 percent of whom said that they took this approach; however, first-time and occasional visitors in group C were also significantly more likely than their group B counterparts to take this approach. It appears as if the app almost broke up the coherence of the family group, or at least encouraged a 'break up and rejoin' approach to the construction of family itineraries. It is easy to see how this might happen when one family member is occupied with the mobile app and other family members wander off to see other exhibits, before coming back together and discussing what each has seen and explored.

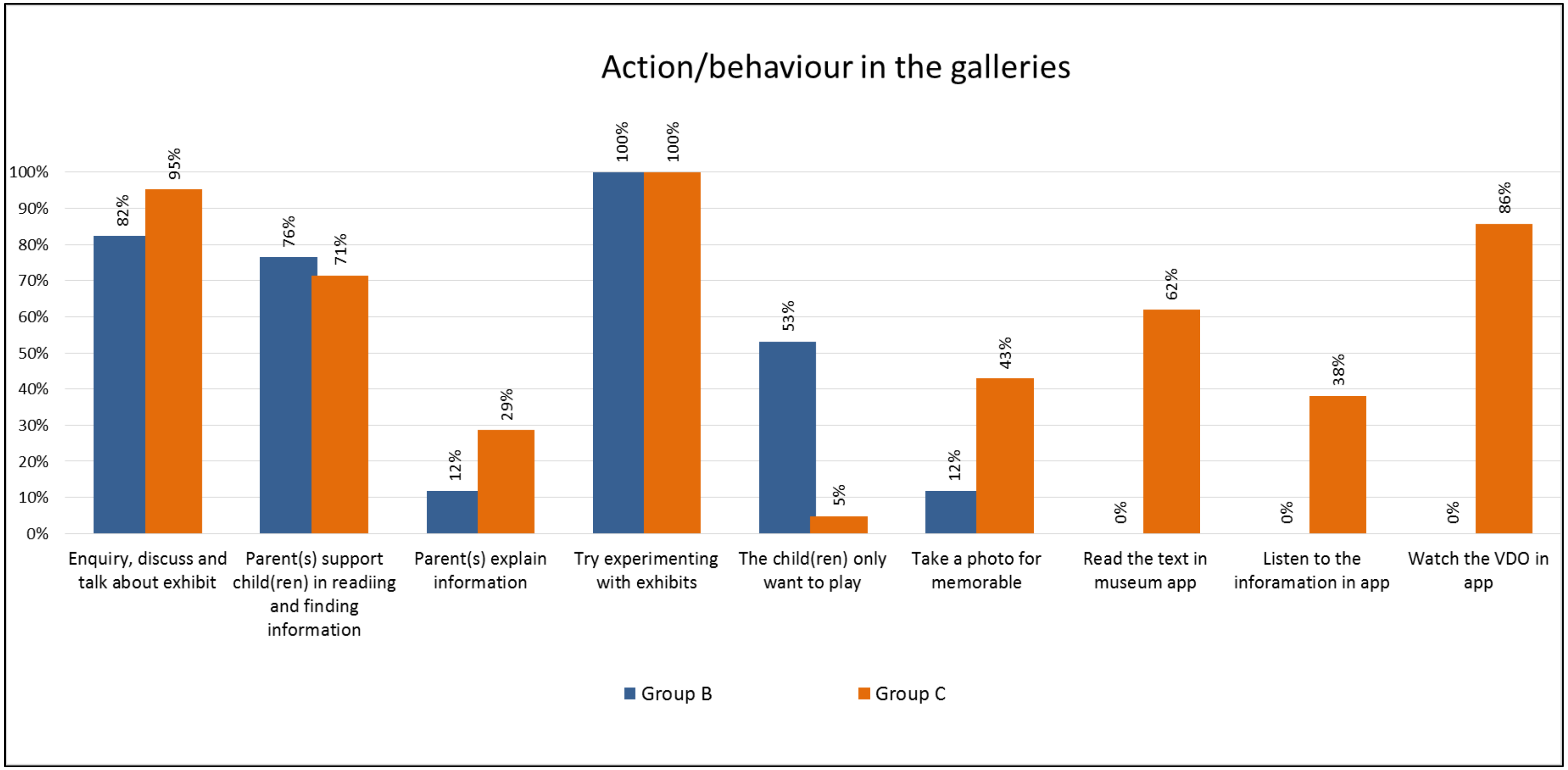



*Figure 6.25 Chart displays the action of family during the museum visit –over all.*

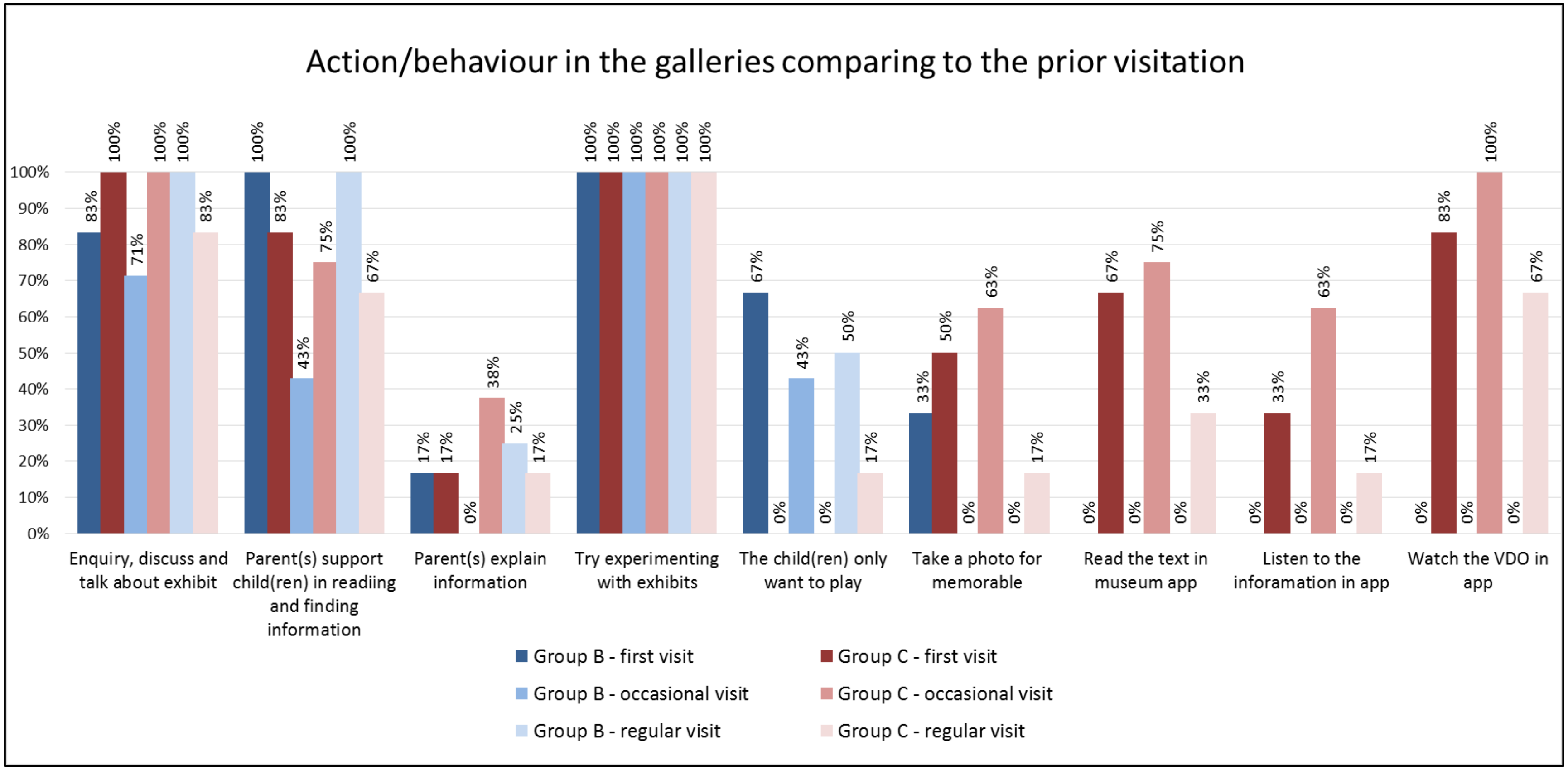



*Figure 6.26 Chart displays the action of family during the museum visit comparing to the prior visitation.*

#### 6.4.2.10 Specific activities in the gallery

The graph in Figure 6.25 and Figure 6.26 above shows the specific activities families reported that they did in the galleries. As can be seen in the graph, enquiry and discussion about the exhibits was reported by most families in both groups. In both group B and C families, adults also supported the children in reading the text panels and finding out information. All families in both groups experimented with the interactive exhibits.

Adults in a small minority of families in group B (12 percent) and a larger minority in group C (29 percent) said they were explaining information about scientific concepts and ideas to the children. The difference between the two groups suggests that the app might have given confidence to adults in more families to play this role of 'explainer' with their children.

A staggering difference can be seen between the percentage of group B families (53 percent) and group C families (5 percent) that reported that their children were more focused on playing with the exhibits and uninterested in learning about the science behind the exhibits. It appears that the app, possibly owing to its multimedia content, made the science content more interesting and less alienating for the young family members.

As expected, families in group C reported their use of the app as one of the things they did in the gallery. It is interesting to note that watching video content was the most commonly reported activity, followed by reading the textual information in the app, followed by listening to audio content. This might be an indicator of visitor mobile media preferences, as well as of what kept the children in group C interested to learn – although the usability issues related to listening to app audio discussed earlier in this chapter may also have influenced this outcome.

Photo taking was reported by nearly half group C families, compared with just over 10 percent of group B families. This actually contradicts data from the video-based observations, the findings of which are discussed in the next section. It might be that group B families were reporting this activity more often because it related with the use of a mobile device just like the app, and so for group C families, photo taking was a legitimate activity that made sense to be reported as an in-gallery activity.

This highlights the need for observational data to complement interview data. As it was not practical to follow families and observe their behaviours throughout the visit, a more localised observational study was designed. This is reported in the following section.

## 6.5 Video-based observations

### 6.5.1 Introduction

The observation part of the research aimed to capture and analyse behaviours of family visitors to the science museum, focusing on how they interact with each other, with museum staff and with exhibit media, and how use of the app impacts these interactions and more generally the length and quality of the family experience. This part of the evaluation was designed to collect data from two groups of family participants, ten families in *Group D who did not use the app* and another ten families in *Group E who did use the app*.

Observation data was collected about the *Plasma Ball* exhibit only, using one of the museum's surveillance cameras which was located at a place where families remain within camera view for most of their engagement time with the exhibit. Visitors to the museum on the observational data collection days were notified that video-recording was taking place at the Plasma Ball exhibit for this research, and asked to notify a member of staff if they had any concerns about the use of the data. Data collection for the two participant groups took place on the same two weekends as for the GLOs study: 18-19 April 2015 for group D and 25-26 April 2015 for group E. However, as video data was completely anonymous, it was not possible to match data from video observations with data from the GLOs interviews, therefore it was not possible to associate family behaviours at the exhibit e.g. with their 'knowledge and understanding' data about the Plasma Ball. Moreover, group D families in the video data may not have taken part in the GLOs group B, as the camera recorded continuously all visitors who interacted with the exhibit on the day rather than those families who had consented to participate in the interviews only. The same is true for group E, as there may have been families who downloaded and used the app on their own, based on the information in the app info panel on the ground floor, without taking part in the GLOs group C study. It was therefore not possible to make direct associations between GLOs and observational video data. Nevertheless, the video data provided a rich source for observations about how the app impacts on family engagement with the exhibit and complement the GLOs interview data by shedding light on the behaviours and interactions that lead to the visit's generic learning outcomes.

The Plasma Ball was chosen for the video-based observation because, of the four focal exhibits, it was the one lying in the middle of the interactivity spectrum. Lucy and the Camera are non-interactive exhibits. The Whisper Dishes are highly interactive as they require participants to perform a certain set of actions in order to experience the phenomenon they demonstrate. The Plasma Ball lies in-between these extremes, as it both demonstrates the phenomenon continuously even without visitor interactions, and reacts to visitors' actions, e.g. placing of hands on different parts of the surface of the ball.

The video recordings of ten families from each group (D and E) were analysed. These were chosen randomly, by selecting a timeframe within the data collection weekend during which the exhibit was busy and analyzing the first ten families to approach the exhibit in that timeframe. The following section explains how video data were analysed.

### 6.5.2 Data analysis method

Coding started by watching each video and noting down, for each family member, the sequence of their actions. A second viewing of the video was then necessary to note how many seconds into the clip each action started. This then enabled us to calculate the duration of each action, by subtracting the number of seconds into the video when the action started from the number of seconds into the video when the next action started.

The second stage of video coding involved the grouping of activities of a similar nature into one distinct action category. Eighteen distinct action categories emerged. Four of these related to the use of the mobile app and were therefore only observed in group E. Evidence of the other 14 distinct actions was found in both group D and E videos. These distinct actions are:

1. **Approach:** Participant comes close and stops at the exhibit.
2. **Move around exhibit:** Participant starts to walk or move around the exhibit.

3. **Encourage participation:** Participant interacts with the exhibit and attempts to motivate another family member to participate and manipulate the exhibit.

4. **Read panel:** Participant is looking at the text panel and appears to be reading it.

5. **Play with ball:** Participant starts to interact with the exhibit, for example puts his or her hand on the exhibit and looks at how the plasma reacts, or tries to manipulate the exhibit by moving his or her hand over the ball, or experiments with the exhibit, or copies what another family member or visitor is doing with the exhibit, etc. Other participants may be playing with the ball at the same time, but there is no direct interaction between participants.

6. **Watch/listen:** Participant is watching others play with the ball, or listens to others talking or reading out loud from panels.

7. **Point and tell:** Participant points at the exhibit and talks to other family members, or appears to be demonstrating to other family members how to use the exhibit, or appears to be guiding others to correct how they are using the exhibit.

8. **Read out loud:** Participant is looking at the text panel and reads the content out loud for other family members to hear.

9. **Talk with family:** Participant talks with other family member(s) focusing on the exhibit.

10. **Scan QR code:** Participant in group E uses their tablet or mobile phone to scan the QR code provided at the exhibit.

11. **Prepare for using app:** Participant starts to bring out their tablet or mobile phone in order to use the mobile application.

12. **Watch/listen to the app info:** Participant is using the app and is watching videos or reads text available on it using the tablet or mobile device.

13. **Watch/listen to the app info together:** Same as 'watch/listen to the app info' but participant is sharing the mobile device with another family member.

14. **Take photo/video:** Participant uses a camera or a mobile phone to take photos or record videos of the exhibit.

15. **Linger not engaged:** Participant remain near the exhibit (within the camera's view) but seems occupied with something else (e.g. talking on the phone, looking away, etc.).

16. **Motion:** Participant is showing signs that he or she is about to move away (e.g. they stop engaging with the ball and look around while other family members are still engaging) or temporarily distracted (e.g. they look up to look for another family member, or pose for another family member to take a photo of them, or look at a photo another family member took of them).

17. **Pull others away:** Participant encourages other family members to disengage and move away from the exhibit (e.g. child pulling adult's arm).

18. **Move away:** Participant moves away from the exhibit and out of the camera view.

The next stage of video coding involved the matching of these distinct actions against Bitgood's (2010) three stages of engagement: capture, focus and engage. For some actions, it was evident how to categorise them. For example, when a visitor approaches an exhibit, it is obvious that it has for some reason captured his or her attention. Similarly, when a family member calls another family member to come to see the exhibit, it is obvious that they are capturing that family member's attention. For one action, however, 'play with ball', the categorisation was not so obvious. The action was observed both as the first thing a visitor does when he or she approaches the exhibit, and as something done after having read a panel, or watched other visitors engaging with it. Bitgood's inclusion of 'touch object briefly' under the 'focus' category, prompted us to differentiate between short and long instances of 'play with ball'.

More specifically, we noticed that the duration of this action ranged considerably, both among visitors and among different instances where the same visitor did this action a number of times during his or her visit to the exhibit. This was an indication that perhaps the same action can be an instance of 'focus' or of 'engage' at different times, for different visitors. We therefore used the following algorithm to characterize an instance of 'play with ball' as focused attention or engagement: if the instance lasted for less than the median duration of this action across all participants, then it was characterized as 'focus'; if it lasted more than the median, then it was characterized as 'engage'. The logic for this decision is also justified by the fact that actions that can be characterized as ‘capture’ and ‘focus’ lasted on average shorter than actions that can be characterized as ‘engage’ (see Table 6.7).

We also noticed that children played with the ball nearly twice as many times as adults did, and did so for longer periods of time. We therefore differentiated between adults and children, calculating median times for adults and children separately for the action ‘play with ball’.

A final decision that had to be made regarding the characterization of ‘play with ball’ as ‘focus’ or ‘engage’, was whether a common duration threshold should be used for both groups D and E. The median time that adults in group D played with the ball during the several instances of this action was 13 seconds, whereas for adults in group E the median was 10 seconds. For children the medians were 19.5 seconds for group D and 17.5 seconds for the group E. As the median values for the two groups were relatively close, the average of the means of the two groups were used as the focus-engage threshold, i.e. 11.5 seconds for adults and 18.5 seconds for children: playing with the ball for less than these times was classified as ‘focus’, whereas playing with the ball for the same or more than these times was classified as ‘engage’.

Three of the observed behaviours could not easily sit with the capture-focus-engage framework. These were ‘motion’, ‘take photo/video’, and ‘linger not engaged’. In all instances where these behaviours were observed, they appeared to distract the participants from engaging with the exhibit. A ‘distract’ category was therefore added to account for these behaviours. Furthermore, some of the observed behaviours always involved at least one other family member. For example, when one family member was reading out loud a text panel, other family members were ‘watching / listening’. These instances were coded as ‘engage together’. Finally, the actions of moving away from the exhibit and pulling other family members to move away from the exhibit were coded as ‘disengage’.

Table 6.7 Coding and Median Durations of Observed Actions

| | | Group D | | Group E | |
|---|---|---|---|---|---|
| Action | Coding | A | C | A | C |
| Approach | capture | 1 | 1 | 1 | 1 |
| play with ball | focus/engage | 13 | 19.5 | 10 | 17.5 |
| Motion | distract | 16.5 | 9 | 2 | 2 |
| encourage participation | capture | 1 | | 4 | 1.5 |
| move away | disengage | | | | |
| pull others away | disengage | | 0.5 | 10 | 2 |
| read panel | engage | 16 | 7 | 10 | 2 |
| point and tell | engage together | 17 | | 10 | 2 |
| watch/ listen | focus | | 17 | 7 | 4 |
| read out loud | engage together | 9 | | 9 | 4 |
| take photo /video | distract | 16 | | 25 | 10 |
| talk with family | engage together | 12 | 9 | 20 | 15 |
| move around exhibit | capture | 1 | 19 | 14 | 4.5 |
| linger not engaged | distract | 7 | 18 | 7 | 4 |
| scan QR code | focus | - | - | 6 | 7 |
| prepare to use app | focus | - | - | 14 | 10 |
| watch/listen app media | engage | - | - | 23 | 5 |
| use app together | engage together | - | - | 27 | 6 |

Table 6.7 above shows how each of the observed actions were coded and the median of their durations in observations for adults and children, in groups D and E. As can be seen in the table, all behaviours were observed in both groups – except the behaviours related to using the app. Four behaviours were only observed in adults in group D (‘encourage participation’, ‘point and tell’, ‘read out loud’ and ‘take photo/video’), and two behaviours were only observed in children in group D (‘pull others away’ and ‘watch/listen’). Both adults and children in group E exhibited all the different behaviours.

Figure 6.27 below shows the frequency of each behaviour in adults and children in groups D and E. As can be seen in the graph, both children and adults in group E played with the plasma ball more often than their group D counterparts, with children in both groups playing with the ball almost twice as often as the adults in the group. Another behaviour that was observed a lot more often in group E is ‘talk with family’: families who used the mobile app talked to each other more than families in group D. This is a clear indication that the app encouraged more verbal interaction between the family members. As both adults and children in group E watched/listened to material in the app equally frequently, it may be that the app material sparked conversations between family members. However, adults in group E exhibited 'point and tell' behaviour less frequently than adults in group D. This suggests that the app may have replaced the adult's 'point and tell' and instead prompted further discussion about the plasma exhibit. Finally, both adults and children in group E were observed 'lingering' a lot more often than those in group D; this lingering around the exhibit may have contributed to the group E families' longer dwell time (see related findings below) and suggests that the app is motivating family members to allow each other as much time as they need to engage with the exhibit. Taken together, the three 'distracting' behaviours ('take photo/video', 'linger' and 'motion') were equally frequent in the two groups. The frequencies of other activities were either comparably low, or there were no significant differences between the two groups. The use of the app in group E was observed more frequently for adults than playing with the ball (if 'watch/listen to the app info' and 'use the app together' are added together). This was not the case for children in group E.

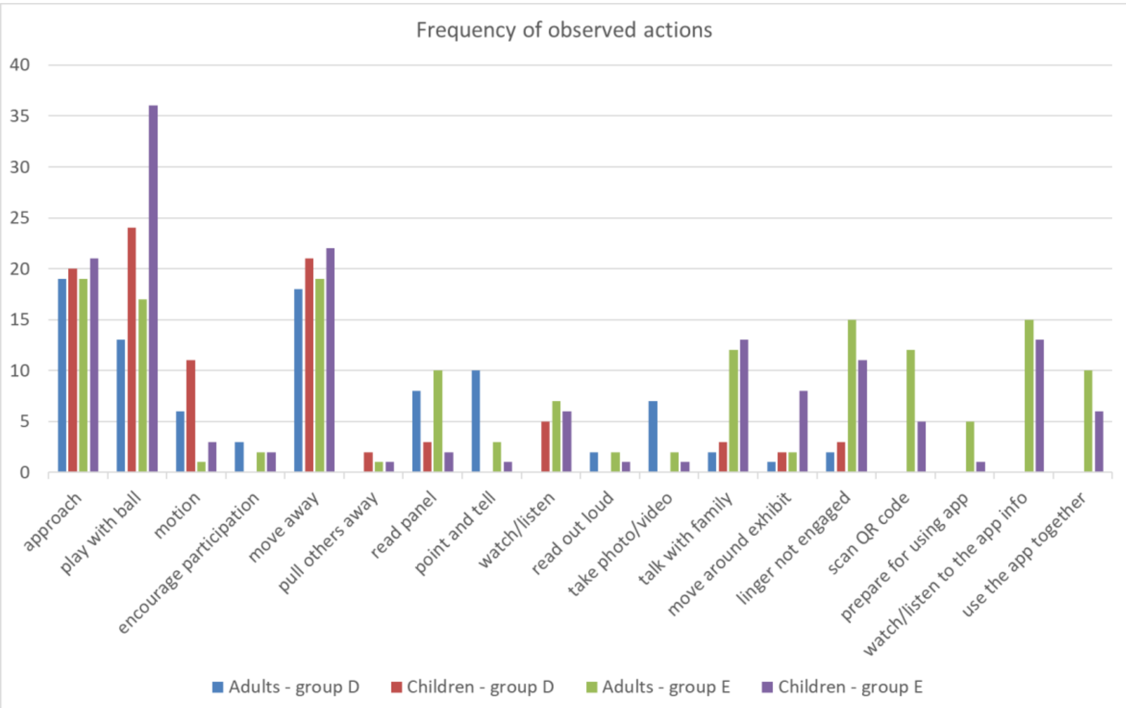



*Figure 6.27 Frequency of behaviours in adults and children in groups D and E.*

### 6.5.3 Comparison of family behaviours between groups D and E

The Figure below shows the percentage of time that adults and children in the two groups spent on activities that indicate states of engagement (capture, focus, engage). It is important to note that both children and adults in group E spent a much larger percentage of their exhibit time engaged with the exhibit as those in group D, with children in group E spending 26% more of their time engaged than children in group D.

The percentage of time spent ‘engaging together’ was larger for adults and children in group E compared with group D. This suggests that the app facilitated all family members’ engagement, and facilitated more family interactions.

Also important to note, is the reduction in the percentage of time spent ‘distracted’, which for group E was approximately four times smaller for adults and three times smaller for children than those in group D. This indicates that the use of the app got families less distracted and more engaged with the exhibit. As the graph shows, adults in group E move faster from ‘capture’ to ‘focus’, and spend longer focusing than adults in group D. This then leads to longer engagement and less distraction time. For children the picture is slightly different, as children in group E do not seem to need less time on ‘capture’, but they do seem to move faster into a state of engagement than their group D counterparts, needing less ‘focused’ time to achieve this. Overall, this graph paints a positive picture for the app, indicating that it achieved its goal of getting families more engaged with the exhibit and with each other.

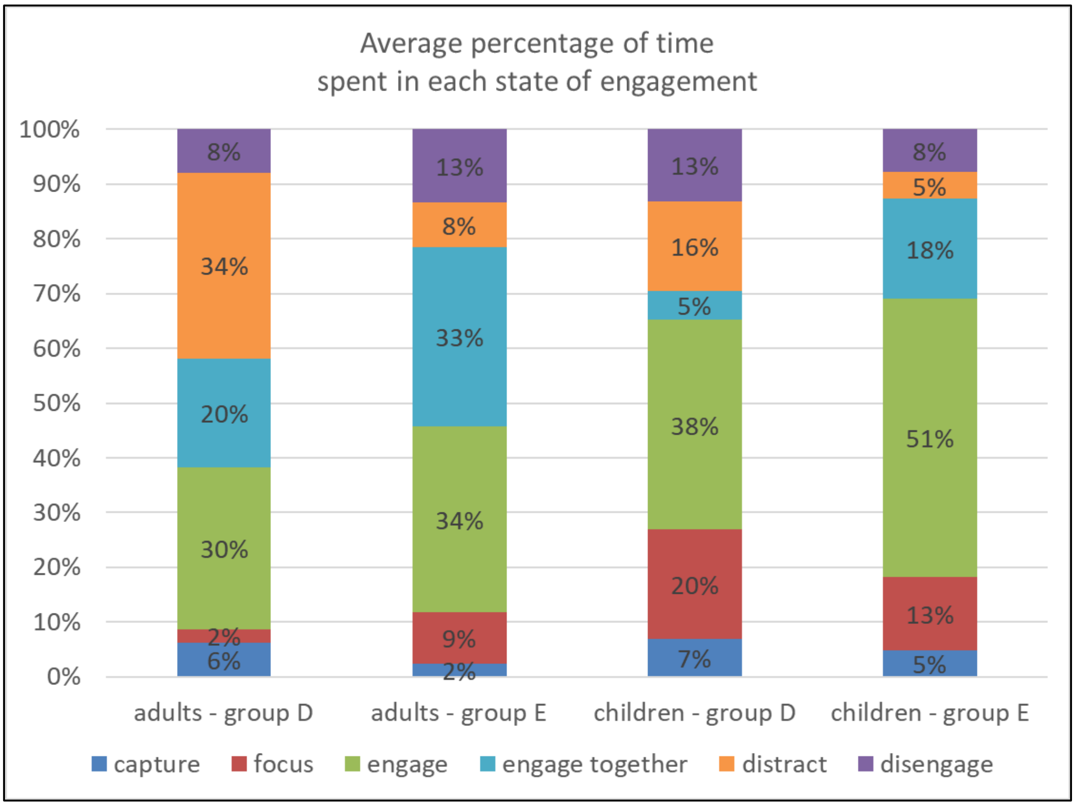



*Figure 6.28 Average percentage of time spent in each stage of engagement from groups D and E.*

What is also important to note is that families in group E did not only spend a larger percentage of their time engaged with the exhibit, they also spent a longer time at the exhibit in absolute terms. Let us define 'Family Dwell Time' as the amount of time between the arrival of the first family member and the departure of the last family member from the exhibit and the recording camera's field of view. The graph in the Figure below shows the average Family Dwell Time for families in the two groups. As can be seen in the graph, group E families stayed on average 180 seconds, more than twice as long as families in group D (82.2 seconds). The median Family Dwell Time for the two groups is also shown on the graph and, as can be seen, is very near the averages. This indicates a normal distribution of Family Dwell Times and excludes the possibility that one group E family might have stayed for far longer than usual and has therefore skewed group E's average dwell time – and similarly, that there was not one single family in group D who stayed for too short a time to skew group D's average.

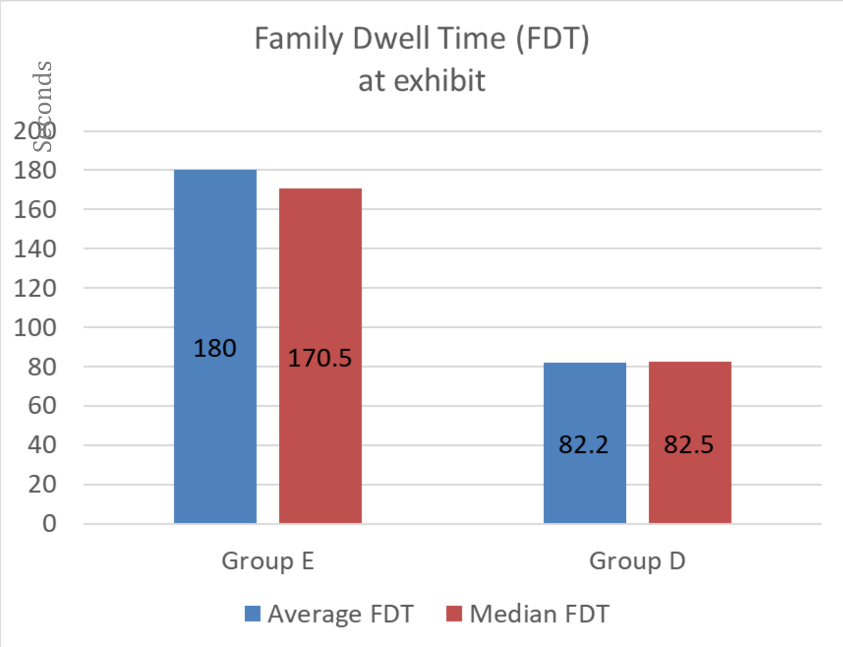



*Figure 6.29 Family dwell time at exhibit from groups D and E.*

We can conclude then that families in group E stayed longer than families in the group D (on average, more than twice as long – see graph above) and they spend a considerably larger percentage of that considerably longer amount of time engaged with the exhibit and with each other. Let us now look more closely at the behaviours of group D families at the plasma ball exhibit.

### 6.5.4 Group D families at the plasma ball

This section presents data from the ten families in group D and discusses their behaviours at the plasma ball exhibit. Figure 6.30 below is intended to give an overview, by presenting a summary of the engagement of all families in group D. The graph shows the percentage of adult time and children time spent in each state of engagement. To calculate this, the amounts of time each adult spent at the exhibit were added and the time spent on capture, focus, engage, engage together, distract or disengage was calculated as a percentage of that sum. So for example if two adults spent 45 seconds each at the exhibit, with the first adult spending 15 seconds on focus and 30 seconds at engage, and the second adult spending 20 seconds on focus and 25 seconds at engage, then the two adults spent a cumulative 35 seconds at focus and 55 seconds at engage out of a cumulative 90 seconds of stay. We would then say that 35/90 or 39% of adult time was spent on focus, and 55/90 or 61% of adult time was spent on engage. The labels of the bars indicate whether it was an adult (A) or child (C) and the identification number of the family, while the number in parenthesis denotes the number of adults or children in the family – e.g. A2(2) denotes (2) Adults in family 2 and C2(1) denotes (1) Child in family 2.

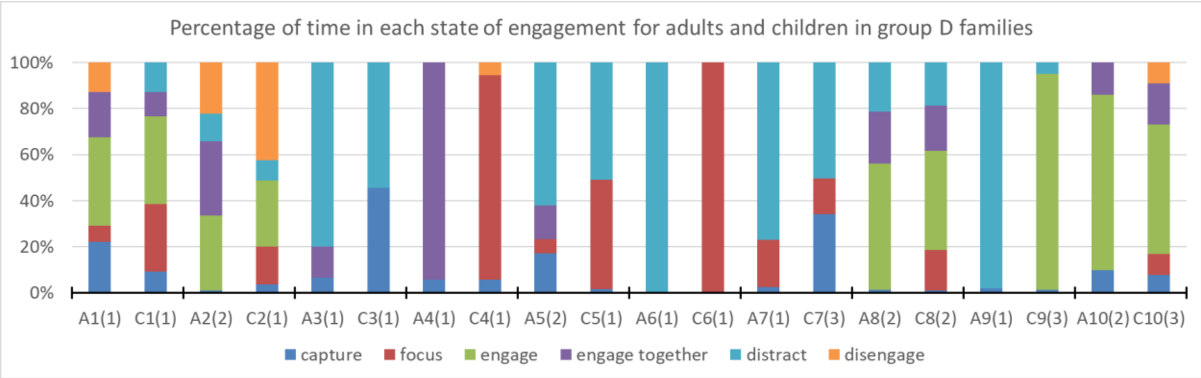



*Figure 6.30 Percentage of time in each stage of engagement for adults and children in group D families.*

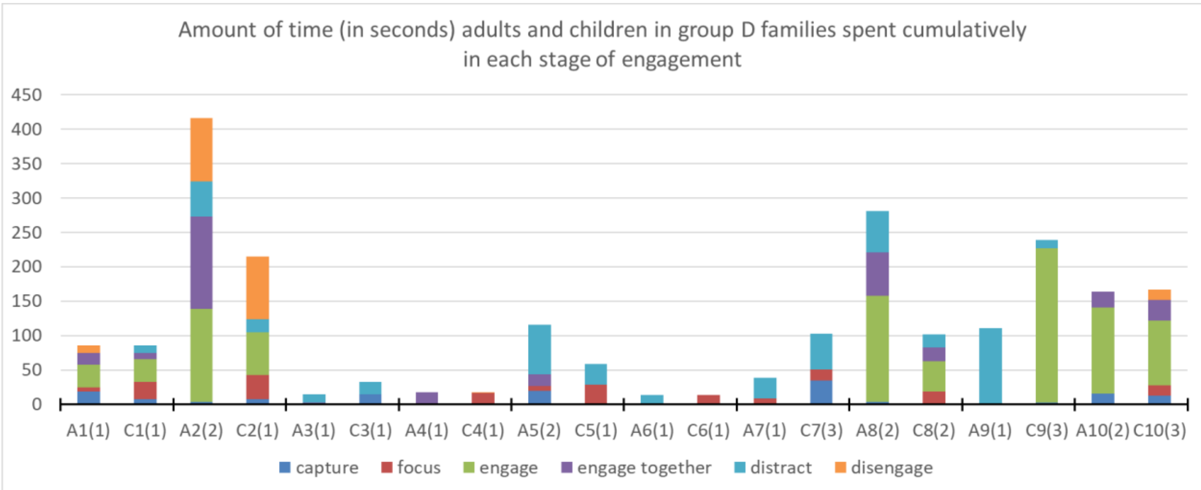



*Figure 6.31 Amount of time that adults and children in a family spent in each stage of engagement from group B.*

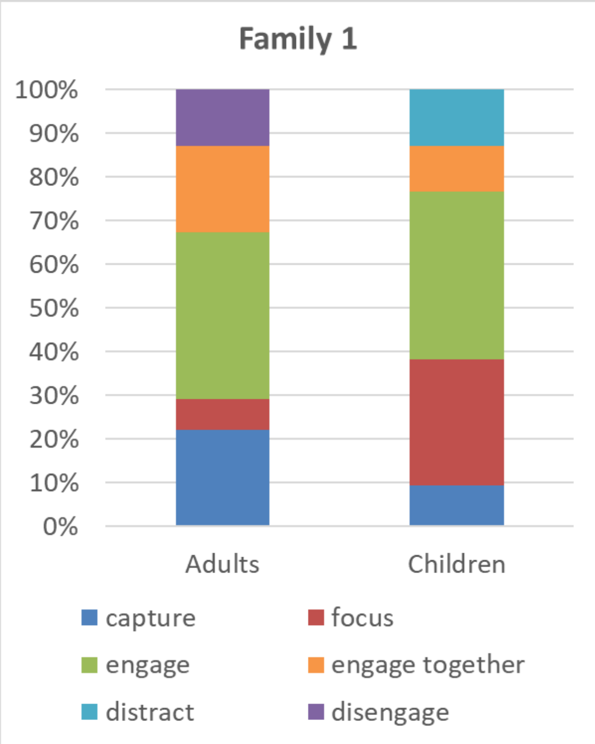
Similarly, the graph in Figure 6.31 shows the amount of time (in seconds) that adults and children in each family spent cumulatively in each state of engagement. Following the example in the previous paragraph, the adult bar for this family would show the 35 seconds the adults spent focusing and the 55 seconds they spent engaging.

Figure 6.31 shows some interesting patterns: in 6 out of the 10 families (1, 2, 3, 4, 5 and 6) the adults and children in the family stay at the exhibit for comparable amounts of time. For example in family 2, where there are two adults and one child, the sum of the two adults' time of stay is approximately twice the child's stay, meaning that all three members stay for approximately the same amount of time. Similarly for the other five families in this sub-group. In families 7 to 10, however, adults and children do not seem to spend similar amounts of time, with some adults spending longer at the exhibit than their children (e.g. family 8). We therefore observe looser and tighter co-visiting behaviours, with some families hanging around an exhibit together for more or less all their dwell time, while members of other families roam more freely and independently of each other.

A final observation that can be made on this graph is that, except for only one family (group D family 9), when the adults in the family stay focused or engaged for at least 50 seconds the children get engaged too.

Each of the 10 group D families is discussed in more detail below.

**Group D Family 1: A missed opportunity for deeper child engagement**



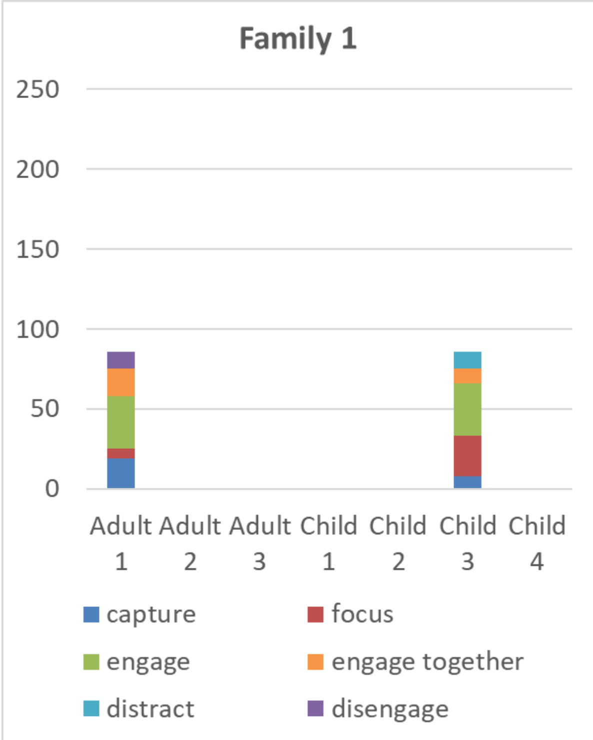




*Figure 6.32 Percentage of adult time and children time spent in each state of engagement by family 1 (left) and amount of time (in seconds) each member of family 1 spent in each state of engagement (right).*

An adult is approaching with a young child, holding the child by the arm. The adult is the first to touch the ball, still holding the child's arm, and talks to the child about the ball. The adult releases the child's arm only when the child's attention has been captured and starts playing with the ball himself. Parent and child keep playing with the ball, talking, pointing and telling for a few seconds. The parent makes a motion to leave and seems to be encouraging the child to follow them. The child is hesitant, and shortly returns to the ball, playing with it a bit more. The adult does not re-engage, however, and eventually the child reluctantly leaves the exhibit and follows the adult.

The adult in this family made the effort to capture and focus the child's attention, but then missed the opportunity to build on the child's engagement. The family engaged for 1 minute and 30'' in total. We are not in a position to know why the adult urged the child to disengage soon after the child's attention had been focused: this might have been because the family had a limited amount of time available and wanted to see as many exhibits as possible in that time, or because the adult did not know what to do with the child's engagement, or because there were other members of the family at another exhibit and the adult wanted to reunite with them (a second adult appears in the camera view briefly looking at the child playing with the ball and swiftly moving on). In any case, it seems that there was a missed opportunity here for the child to engage with the exhibit more.

**<u>Group D Family 2: The adults are pivotal to younger children's engagement</u>**

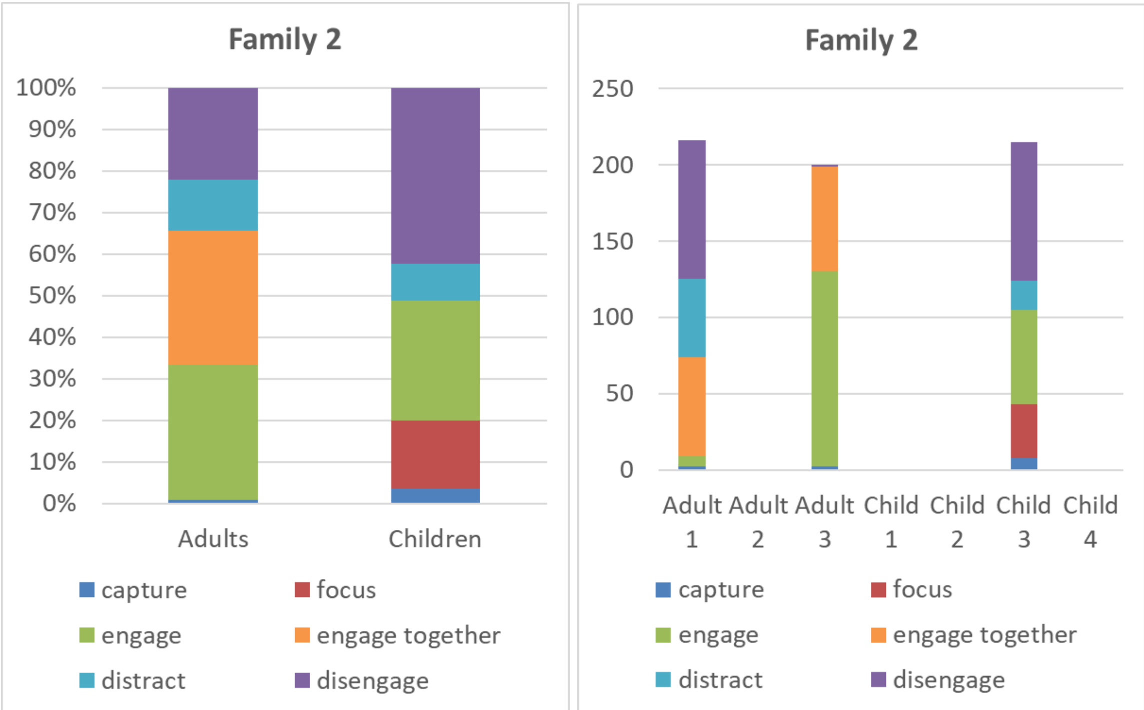



*Figure 6.33 Percentage of adult time and children time spent in each state of engagement by family 2 (left) and amount of time (in seconds) each member of family 2 spent in each state of engagement (right).*

One adult approaches the exhibit with a young child. The adult demonstrates how to play with the ball while the child is watching and asking question. The child then starts playing with ball, imitating the adult's action. A second adult approaches and starts playing with the ball too. The first adult then takes out a mobile device and starts taking photos of the child at the ball, while the second adult keeps the child focused on the play by showing the child how to touch the plasma ball. Soon after the first adult has finished taking photographs, the second adult stops showing the child's what to do and starts reading the panel. The child loses focus and moves away with the first adult, while the second adult stays on and keeps reading the text panels. The child returns and pulls the second adult away, holding their hand. The second adult returns a few seconds later to read the rest of the panel. The child and the first adult approach the exhibit again, waiting for the second adult to finish reading. The second adult briefly touches the ball and seems to explain something to the child and first adult, before they all move away from the exhibit.

Despite the young age, the child did engage with the exhibit – albeit only while the adults were trying to capture the child's attention. When the first adult got distracted with photo taking and the second adult got absorbed with the text panel, the young child also lost his focus.

**<u>Group D Family 3: Other visitors may adversely affect a family's engagement</u>**

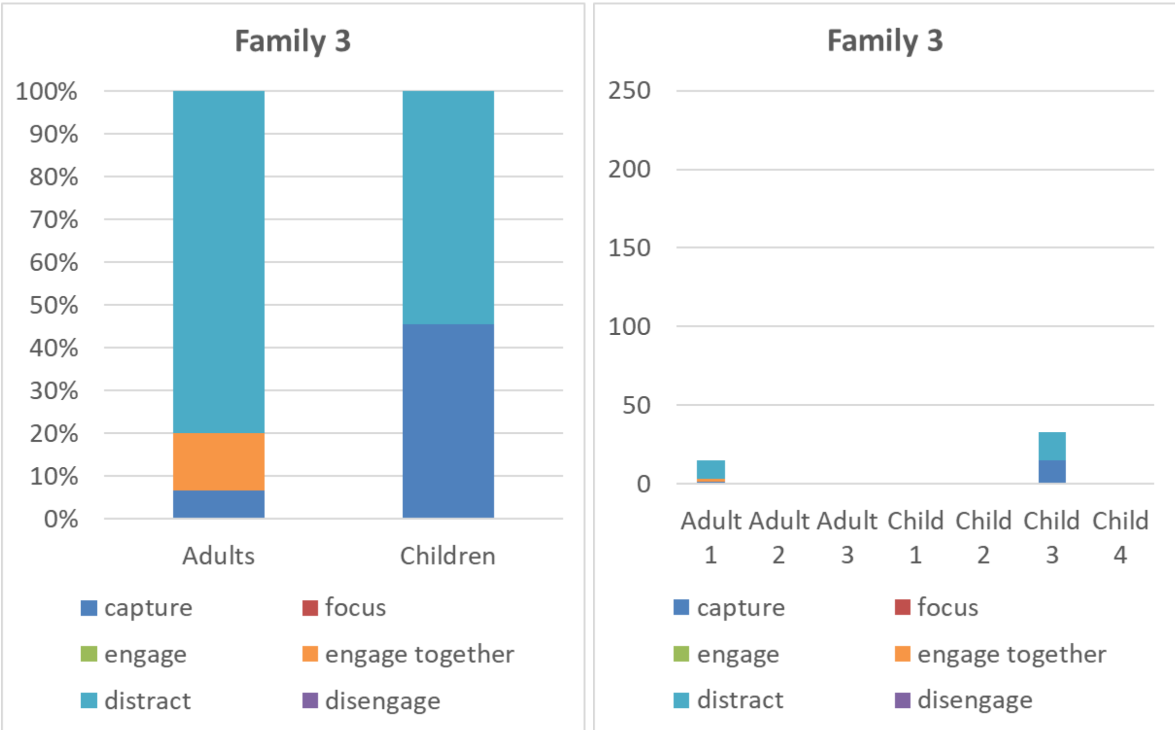



*Figure 6.34 Percentage of adult time and children time spent in each state of engagement by family 3 (left) and amount of time (in seconds) each member of family 3 spent in each state of engagement (right).*

The child (mid-primary school age) approaches the plasma ball and starts playing with it while an adult from another family (group D family 2) is reading the text panel. The child motions to leave when its accompanying adult approaches the exhibit, but the adult has taken a mobile phone out and instructs the child to go back to the ball and pose. The child follows the instructions and plays with the ball for a bit longer, waiting for the adult to take the photo. After taking the photo, the adult approaches the ball and places a finger on it to demonstrate the effect to the child. They both leave immediately after, having stayed at the exhibit for just 33 seconds.

The presence of another person who is not a member of the family may have influenced the behaviour of this family, who thus only stayed long enough to capture a photo.

**<u>Group D Family 4: Some family visits are very brief</u>**

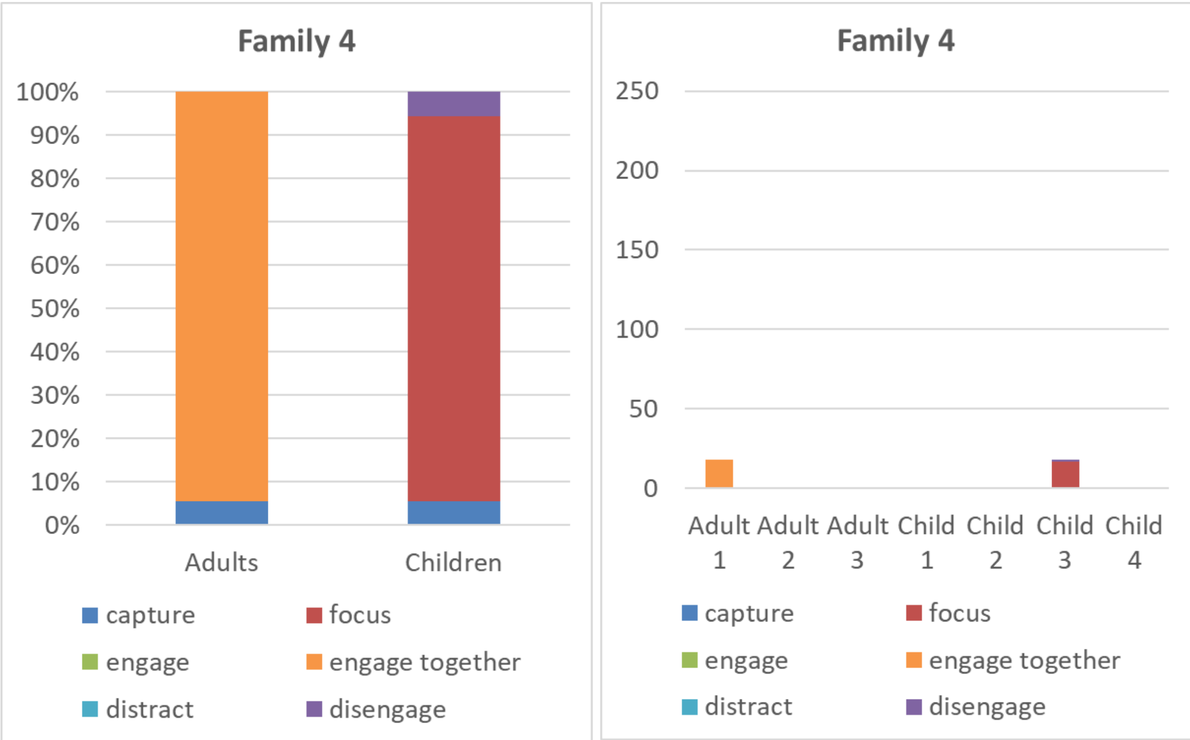



*Figure 6.35 Percentage of adult time and children time spent in each state of engagement by family 4 (left) and amount of time (in seconds) each member of family 4 spent in each state of engagement (right).*

One adult approaches the plasma ball with a young child and a baby in arms. The family spends less than 20 seconds at the exhibit, with the adult showing to the young child how the ball works and the two of them playing with the ball. The visit is too short to allow the child to engage, despite the adult’s engaging interaction with the child.

**Group D Family 5: Capturing (info for later) while captured (by the exhibit)**

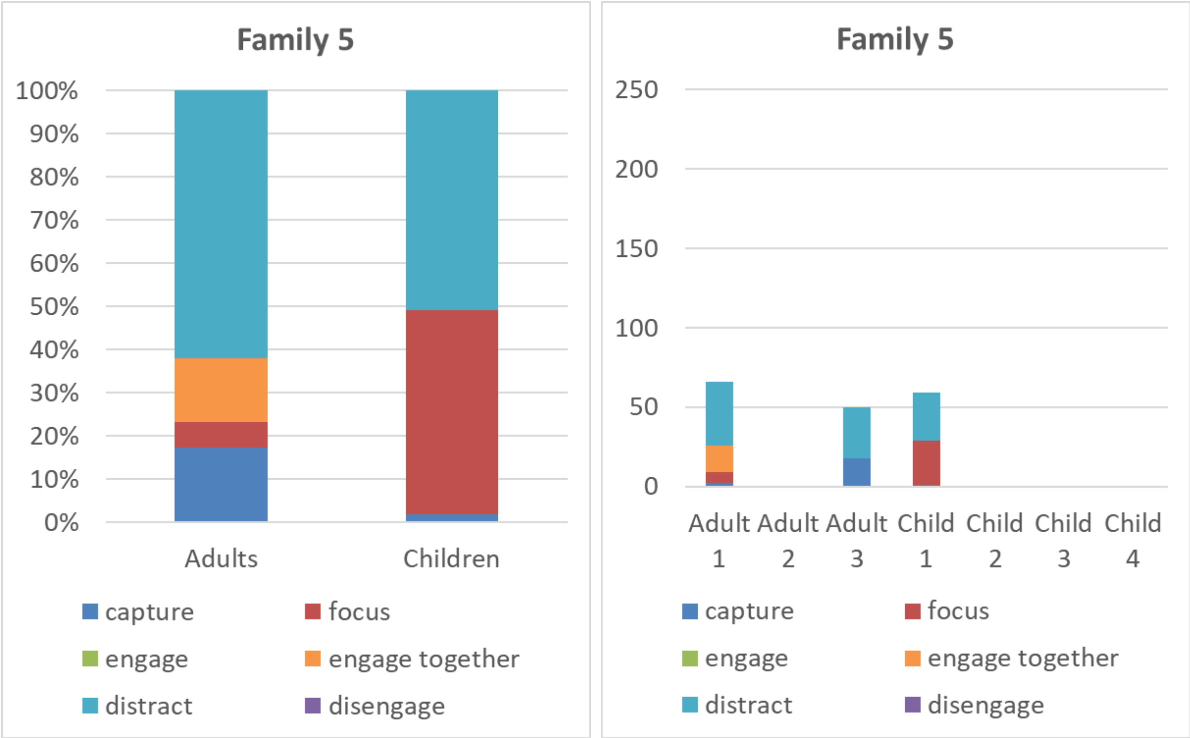



*Figure 6.36 Percentage of adult time and children time spent in each state of engagement by family 5 (left) and amount of time (in seconds) each member of family 5 spent in each state of engagement (right).*

An adult approaches and starts playing with the plasma ball. A child (mid-primary school age) joins the adult and the two play together briefly, before the adult starts reading out loud the text panel. A second adult approaches and listens in too. The first adult then takes out a tablet and both adults step back to take a picture of the child at the plasma ball, who has meanwhile been playing with it. After the photo taking the second adult and the child move away. The second adult comes back a couple of seconds later, sees that the first adult is about to take a photo of the text panel, and moves away again. After taking a photo of the panel, the first adult moves away too.

This family's behaviour is somewhat similar to the photo takers (group D family 7 below), however, this family engages not only with the interactive part of the exhibit (ball) but also with the surrounding interpretive elements (text panels). The fact that they take photographs of the text panels might be indicating that they intent to follow up their learning about the plasma ball after the visit.

**<u>Group D Family 6: Some family visits are briefer than brief</u>**

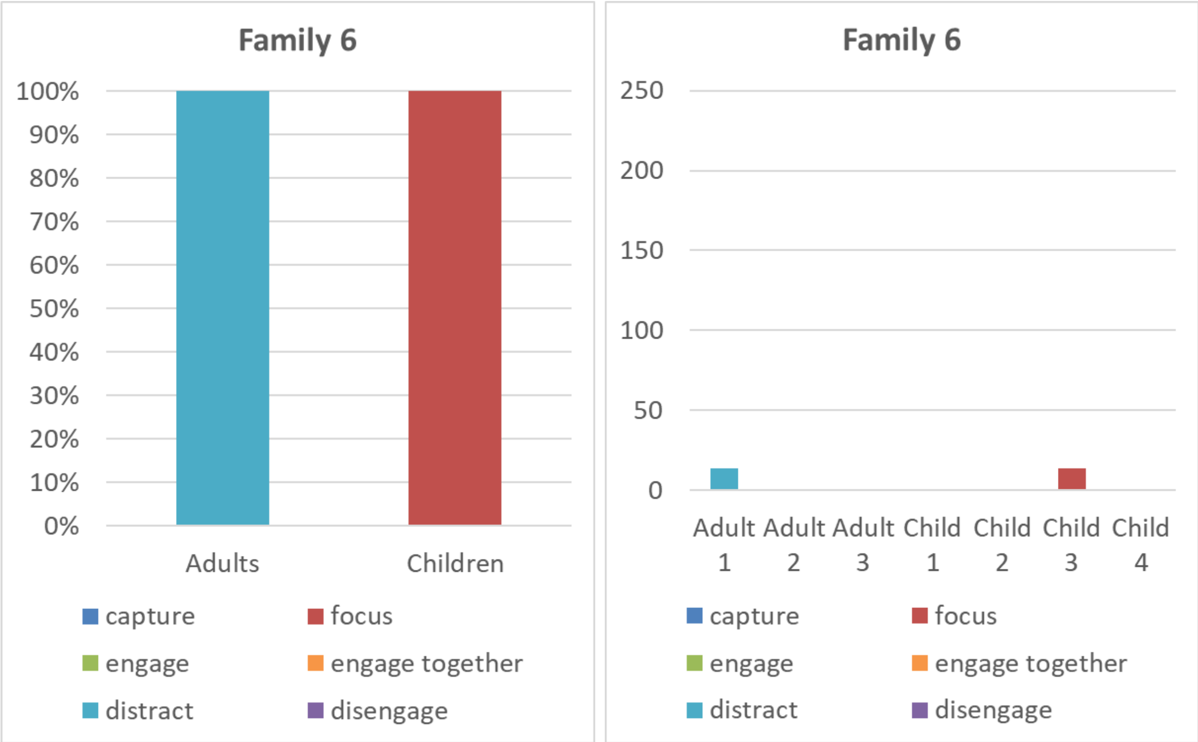



*Figure 6.37 Percentage of adult time and children time spent in each state of engagement by family 6 (left) and amount of time (in seconds) each member of family 6 spent in each state of engagement (right).*

This is the shortest family visit observed, lasting a mere 14 seconds: one adult and one child approach the ball, the child briefly plays with it while the adult talks on their mobile phone and only momentarily touches the ball, then immediately moves away. The child follows them soon after. The adult never moves past the captured attention state of engagement, while the child has only just achieved focused status.

**Group D Family 7: Some families are preoccupied with capturing their visit (and fail to be captured by the exhibit)**

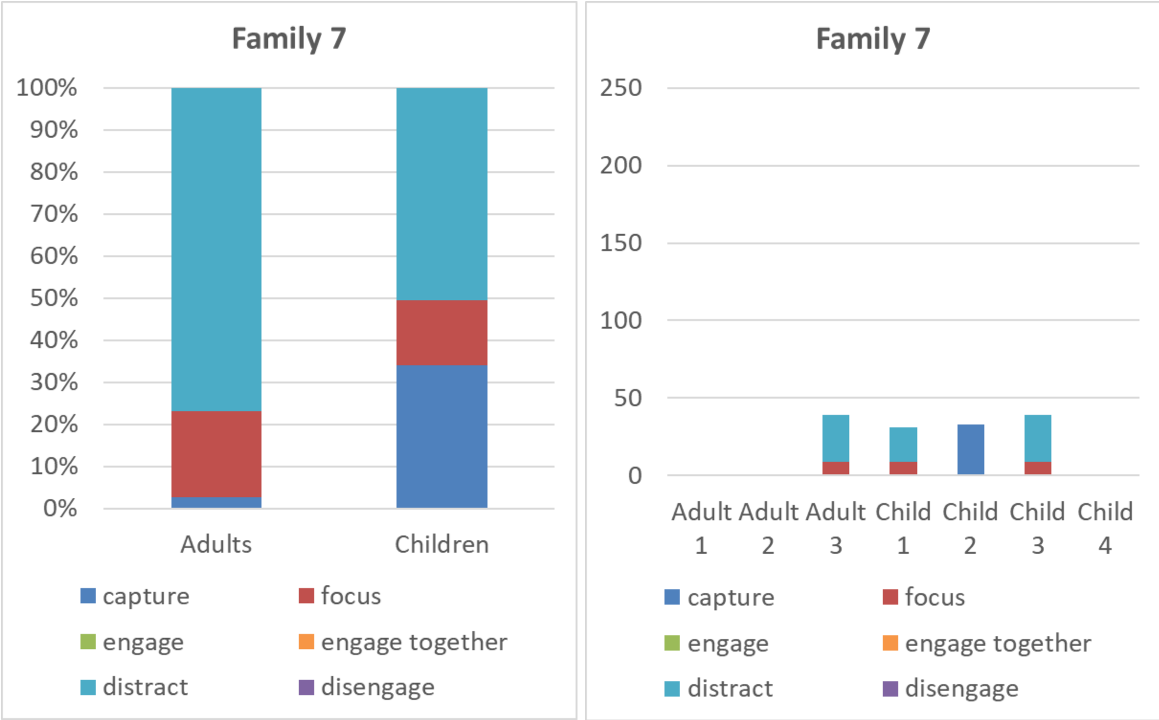



*Figure 6.38 Percentage of adult time and children time spent in each state of engagement by family 7 (left) and amount of time (in seconds) each member of family 7 spent in each state of engagement (right).*

One older child (late-primary school age) approach first, followed shortly after by another child of similar age, an adult and a younger child (mid-primary school age). They all touch the exhibit briefly, and within seconds the adult produces a mobile phone and gets the children to pose for a photograph. The younger child steps back, staying out of the phone's viewfinder and watches the photo taking and the ball. After the adult had taken the photo and shown it to the older children, they all touch the ball briefly and leave soon after. The younger child touched the ball only with one finger, looking a bit worried as she did so. The family's dwell time was 40 seconds. It appears that this family left with a photo of two of the children at the exhibit, and the third child wondering what this 'machine' is. In spending most their dwell time on photo taking, the family's visit to this exhibit did not take advantage of the obvious curiosity about the exhibit of the younger child and did not give an opportunity to the older children to question the exhibit.

It appears that photo taking was the purpose of this family's engagement with the exhibit. While the video data suggest that on this occasion photo taking was getting in the way of meaningful engagement, its potential to provide a record of the activity that can post-visit spark further enquiry should not be dismissed (recall the photographing of text panels by family 5 earlier). Nevertheless, the enquiry potential of the exhibit itself seems to have been lost for this family, who did not engage with any of the exhibit's interpretive elements (e.g. did not stop to read the text panels).

**<u>Group D Family 8: Capturing (memories of the visit) after being captured (by the exhibit)</u>**

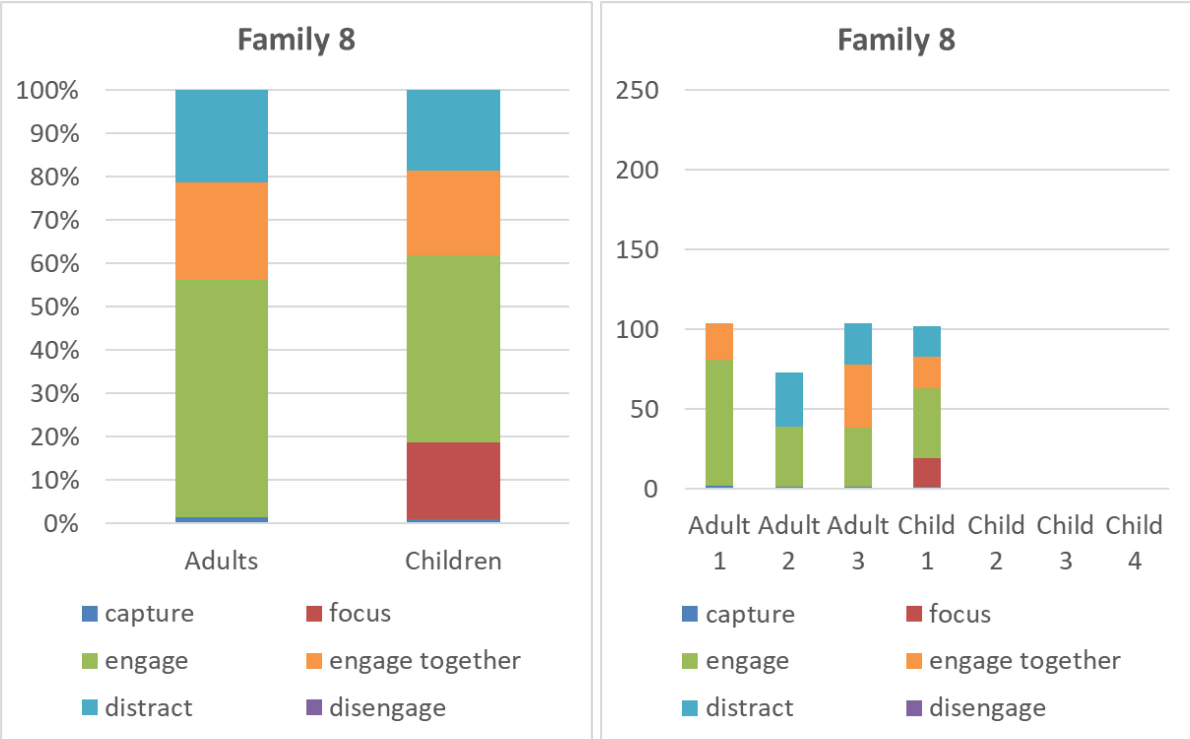



*Figure 6.39 Percentage of adult time and children time spent in each state of engagement by family 8 (left) and amount of time (in seconds) each member of family 8 spent in each state of engagement (right).*

Two adults and one child approach the plasma ball and start playing with it. The two adults encourage the child to touch the ball and place her hand at different locations. A third adult approaches and the four of them all play together for a few seconds. Two of the adults then switch to reading the text panels while the third adult takes out a mobile phone to take a photograph of the child at the ball. The child loses interest and turns away, but the photo-taker asks the child to play with the ball again. The child does so, playing with the ball again and looking at it, but one of the other two adults holds the child's head and turns it to face the photographer rather than the ball. After the photo of the child has been taken the whole family move away from the exhibit, having stayed for one minute and 45 seconds. This was another instance where photography signaled the end to the family's engagement with the exhibit.

**<u>Group D Family 9: Engagement as performance?</u>**

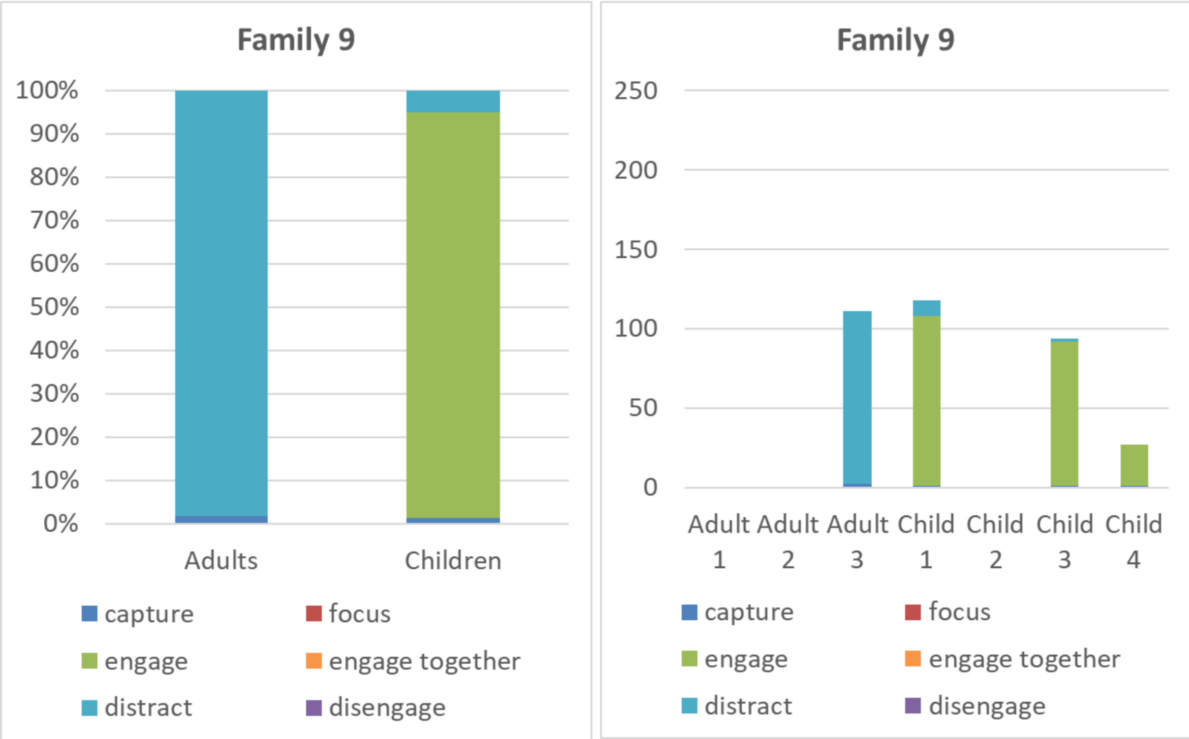



*Figure 6.40 Percentage of adult time and children time spent in each state of engagement by family 9 (left) and amount of time (in seconds) each member of family 9 spent in each state of engagement (right).*

A young child (mid-primary school age) approaches the ball and starts playing with. The child looks very absorbed, touching the ball and watching how it reacts. About 40 seconds later, an adult and a second, younger child (early primary school age) approach. The adult is holding a tablet computer and seems to be video-recording, while the second child joins the first in playing with the ball. Both children are absorbed in their play, experimenting with different ways to touch the plasma ball. The adult moves around the exhibit, tablet in hand, video recording from different angles. At about 2 minutes after arriving at the ball, the first child moves away and a third child joins and starts playing with the ball. Soon after the second child also moves away, leaving the third child playing alone at the ball. A few seconds later the third child steps back, watches the ball for a few more seconds, then moves away. The last child moving away signals the adult to stop video recording and move away too.

The adult in this family did not engage with the exhibit at all, yet all three children played with the ball long enough to reach engagement. The children were aware however that their experience was video-recorded. This may have given them impetus to continue 'performing', and so video recording on this occasion did not act distractingly as photo taking did for other families. The family stayed at the exhibit for almost two and a half minutes, one of the longest family dwell times in group D.

**<u>Group D Family 10: Engaging separately then together</u>**

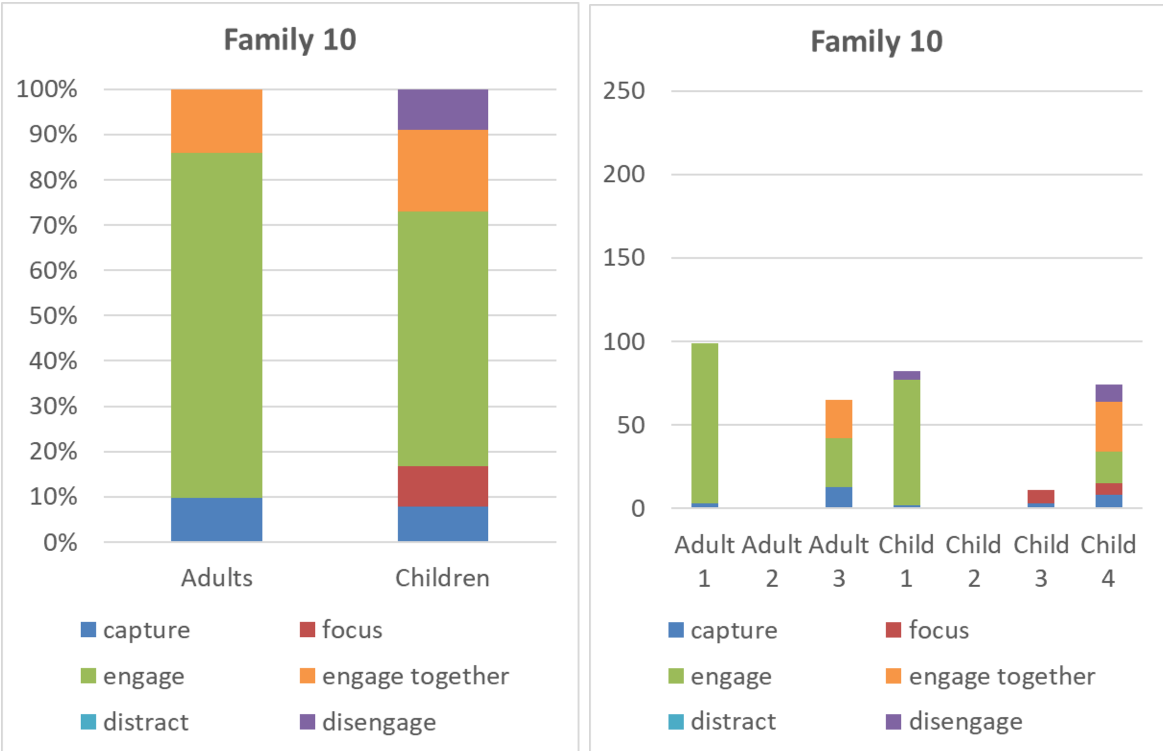



*Figure 6.41 Percentage of adult time and children time spent in each state of engagement by family 10 (left) and amount of time (in seconds) each member of family 10 spent in each state of engagement (right).*

One teenage child plays with the ball and is soon joined by an adult, a second child of similar age, and a third younger child (late-primary school age). A second adult joins them shortly after. The children play with the ball while the adults read the text panels. There is no interaction between adults and children for the first 30 seconds, they are just co-present, the adults reading the panels and the children playing with the ball. The second child moves away, but the other two children and the adults remain and they all play together, experimenting with the ball. The second adult and the first child read the text panels, then the second adult starts reading out loud. The whole family engages in conversation and experimenting with the ball, then they all move away together. This family's dwell time was approximately one and a half minutes. Although not the longest dwell time, all family members but one (second child) engaged both in conversation and experimental play with the ball.

### 6.5.5 Group E families at the plasma ball

This section presents data from the ten families in group E and discusses their behaviours at the plasma ball exhibit. The Figures below provide an overview, by presenting a summary of the engagement of all families in group E. The graph in Figure 6.42 shows the percentage of adult time and children time spent in each state of engagement, while the graph in Figure 6.43 shows the absolute amount of time that adults and children spend cumulatively at the exhibit.

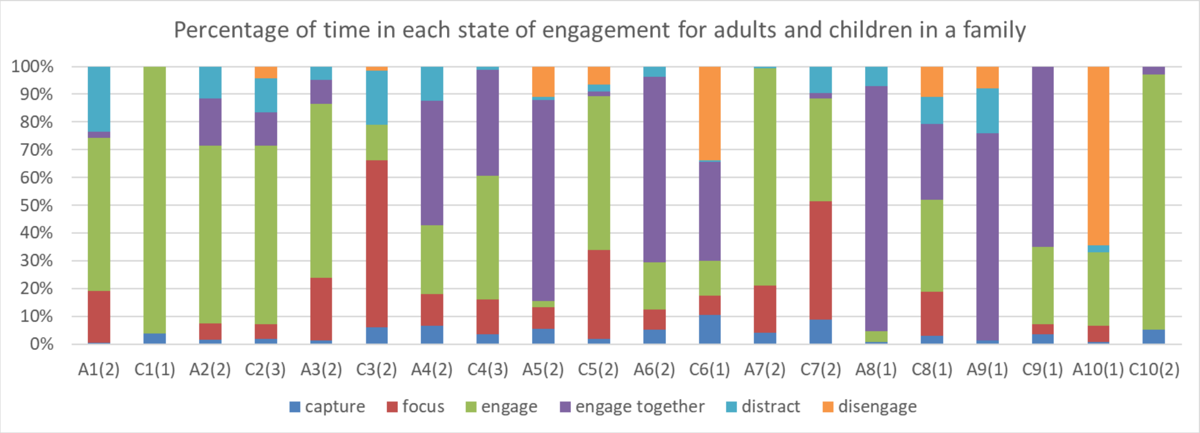



*Figure 6.42 Percentage of time in each stage of engagement for adults and children in group E families.*

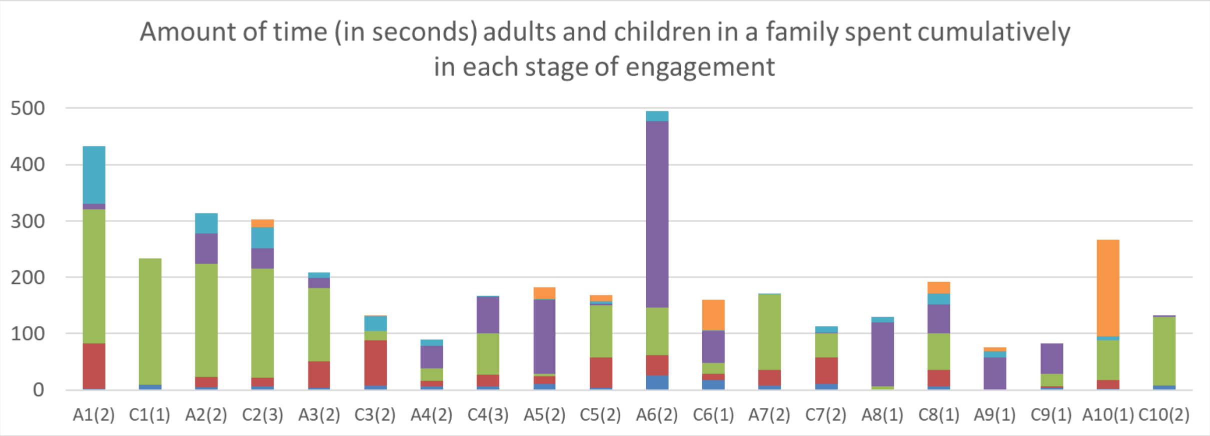



*Figure 6.43 Amount of time that adults and children in group E families spent in each stage of engagement.*

Compared with the patterns observed in group D, it appears that more families in group E (7 out of 10) exhibit looser co-visiting behaviours, with only 3 families' (families 1, 5 and 9) members spending approximately the same amount of time at the exhibit. In 3 of the 7 families with loose co-visiting behaviour the children seem to have spent more time at the exhibit than adults, while in the other 4 the adults spent longer at the exhibit than the children. Bearing in mind the small sample size in the two groups, we have an indication (rather than proof) that the app encourages looser co-visiting behaviour in terms of time spent at the exhibit.

One important difference with the group D patterns presented earlier is that children in all the group E families engaged with the exhibit, and adults in these families stayed focused or engaged for at least 56 seconds with the exhibit. We can therefore claim that the 50 second adult engagement precondition for child engagement also holds for group E, and conclude that the app facilitates adult engagement beyond the threshold 50 second required for child engagement, therefore use of the app results in all children reaching engagement.

Each of the 10 group E families is discussed in more detail below.

**Group E Family 1: Play, learn, play some more**

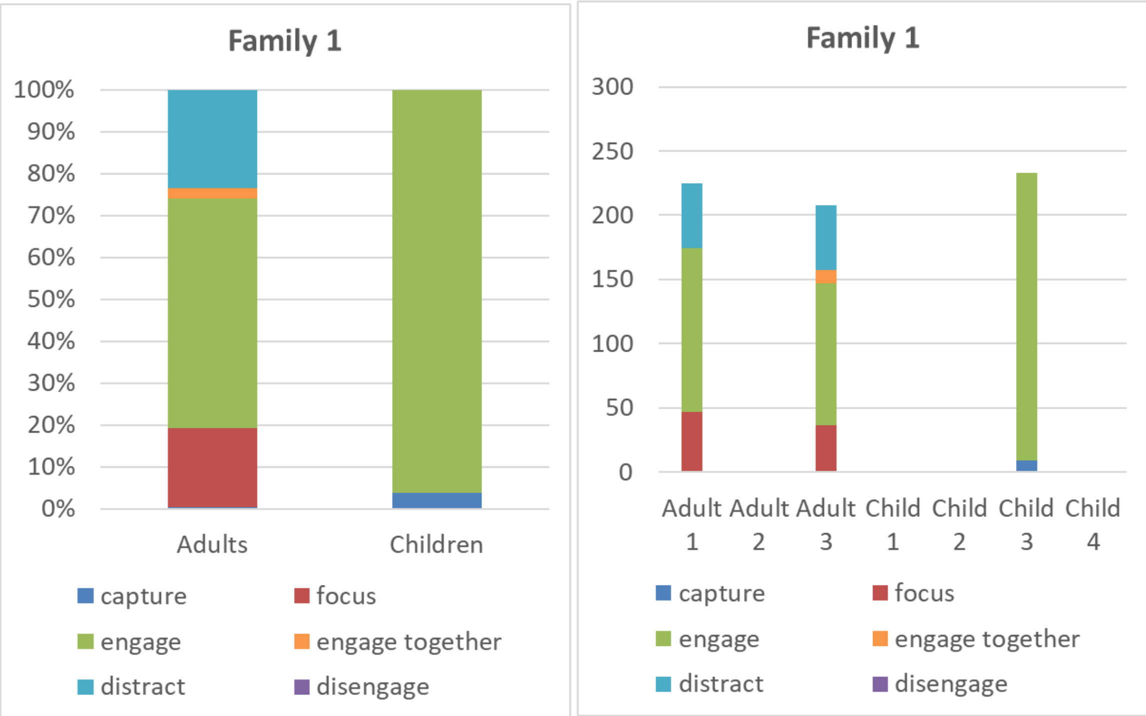



*Figure 6.44 Percentage of adult time and child time spent in each state of engagement by family 1 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

A child approaches the plasma ball and starts playing with it while another family is about to leave the exhibit. The first adult approaches. A second child from another family approaches and looks at the ball. The first adult starts playing with the ball together with the child and they talk to each other. The second child points at the ball, then looks for his family and leaves while the child still talks and plays with the ball with the first adult. After a short time, the first adult looks at the panel, then takes their phone out and tries to scan the QR code and looks at the phone while a second adult approaches the exhibit. On arrival, the second adult starts talking with the child and touches and points at the ball while the child is still playing and talking to the second adult. (The second child who is not a family member returns to the ball and plays with it while the family stand there, then leaves.) The first adult looks at the app screen and shows it to the second adult while the child continues playing with the ball. The second adult takes their phone out and scans the QR code. The adults use the app each on their own device and start comparing their device screens. After playing with the ball for almost two minutes, the child joins the first adult to watch and listen to the information on the mobile app. After nearly forty seconds of using the app and playing with the ball together, two other visitors approach and touch the ball. The first adult takes some photos of the child at the Plasma ball as well as pictures of the plasma exhibit itself before leaving.

The child enjoyed playing with the exhibit while the adults were using the app, thus allowing the child plenty of time to spend at the exhibit. The adults then shared the app with the child, then the whole family spent time engaging with the exhibit together.

**Group E Family 2: The app enthusiast adult**

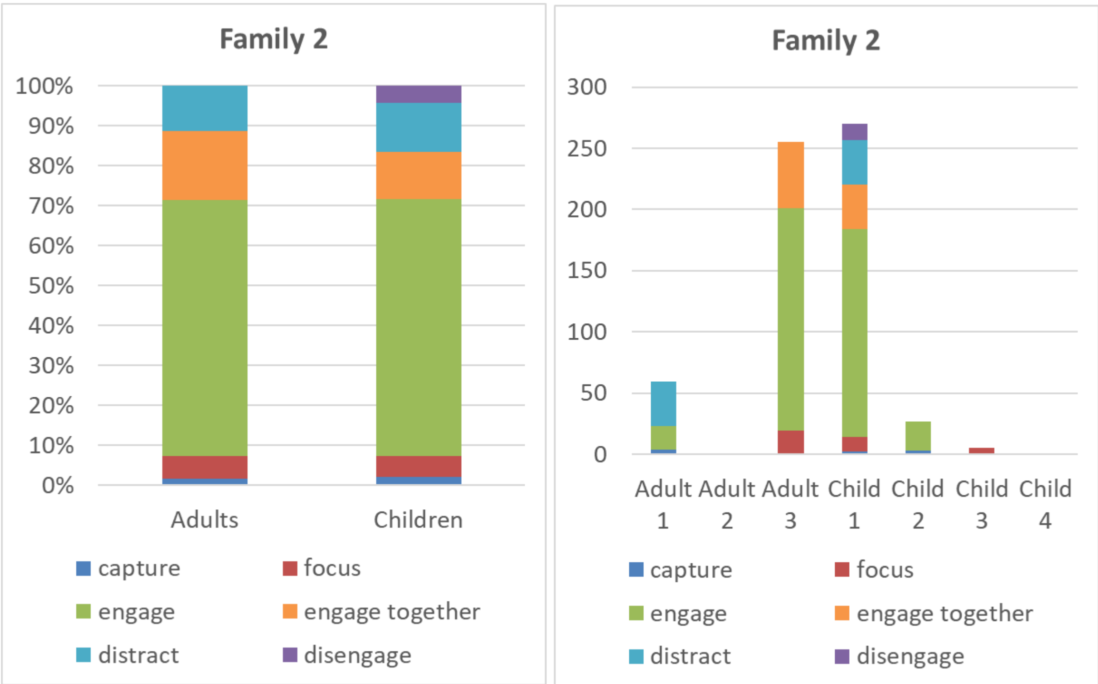



*Figure 6.45 Percentage of adult time and children time spent in each state of engagement by family 2 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

A child (early primary school age) approaches the exhibit and starts playing with the ball. A few seconds later, an adult approaches and starts talking to the child. The adult holds a mobile phone and begins using the mobile app to scan the QR code at the exhibit. After the first adult finishes scanning the code and obtains the information, the child joins them in looking at the screen while still touching the exhibit. They both spend about 30 seconds on the app. Then the child returns to the ball, playing and looking at it whereas the adult is still engaged with the app. While doing so, the adult tries to get the child's attention to the app but the child seems more interested in playing and looking at the ball.

About a minute later, a second adult joins them at the exhibit while the child is still playing with the ball and the first adult is using the app. The first adult shows the app to the second adult, walks around, and points at the ball. The second adult joins the child in playing with the exhibit for about twenty seconds before stepping back and moving away. After the second adult leaves, the first adult continues to use the app and looks at the graphic panel while the child is still playing with the ball. A few seconds later the child moves away to follow the second adult at the same time as a second child (early primary school age) approaches the exhibit and spends only a few seconds touching and looking at the ball before looking around and leaving. While the first adult is still using the app, a third child (mid-primary school age) approaches the exhibit and plays with it. A few seconds later, the first child returns and joins the third child in playing with the ball for about twenty seconds before the third child steps back and leaves. The first adult continues to use the app, then plays with the exhibit with the first child for about two minutes. First adult and child then leave the exhibit.

Overall, the children in this family were more interested in playing with the exhibit whereas one of the adults was more interested in using the app and reading the text panels. This individual made several attempts to engage the other members of the family with the app but was unsuccessful. Nevertheless, this individual’s long engagement with the app encouraged other family members to engage with the interactive exhibit more. What is more, the ‘app user’ then engaged themselves in family interactions with the exhibit, thereby possibly ‘transferring’ what they learned from the app to the rest of the family.

**Group E Family 3: The app enthusiast child**

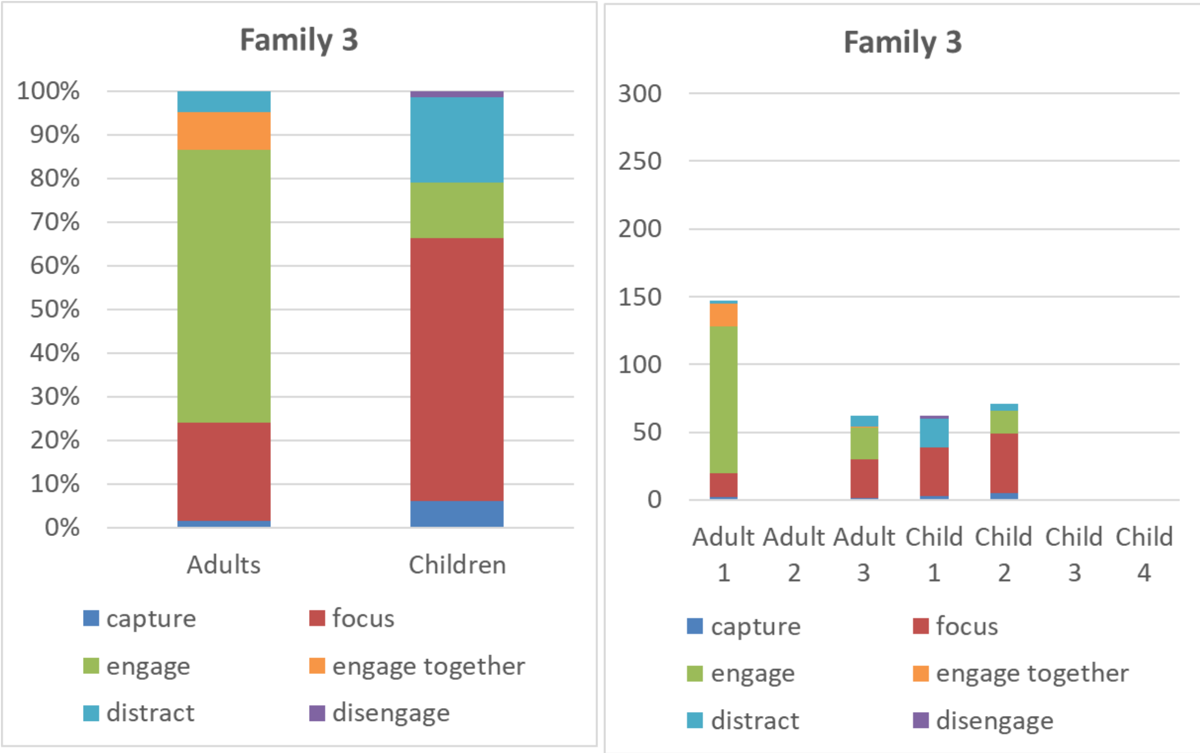



*Figure 6.46 Percentage of adult time and children time spent in each state of engagement by family 3 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

A family of four comprising two adults and two children approaches the exhibit. The first adult and the first child play with the exhibit for a few seconds, then the second adult and the second child, who holds a tablet in their hand, join them and spend about fifteen seconds playing with the exhibit. The second child then starts to use the app on the tablet while the others are still playing with the exhibit and talking to each another. A few seconds later, the first adult starts to read the text panel, whereas the second adult begins to read the panel out loud while still play with the ball with one hand. This pattern continues, with the second child using the app and the rest of the family playing with the ball and talking. The first adult begins to show interest in the app but must turn their attention to the first (younger) child, who attempts to walk away. This causes the second child to stop using the app and follow them. Meanwhile, the second adult is still playing with the exhibit. At some point, a child from another family comes and starts playing with the ball but the second adult remains at the exhibit, interacting with it while reading the text panel for around thirty seconds. After that, the adult takes out their mobile phone and tries the app for a few seconds while continuing to interact with the ball, then leaves. The family dwell time was 150 seconds in total.

In this family, it was the child who carried and looked after the device and used the app. The adults paid more attention to the exhibit and looking after the younger child, engaging with the app only in passing. There was little interaction between family members: one adult was looking after the young uninterested child, the other adult was engaged with the exhibit and the text panels, and the other older child engaged with the app. It would be interesting to know if, after the visit, the child discussed their experience with the app with the adults and/or used the app again after the visit.

**Group E Family 4: Teamwork for interactions**

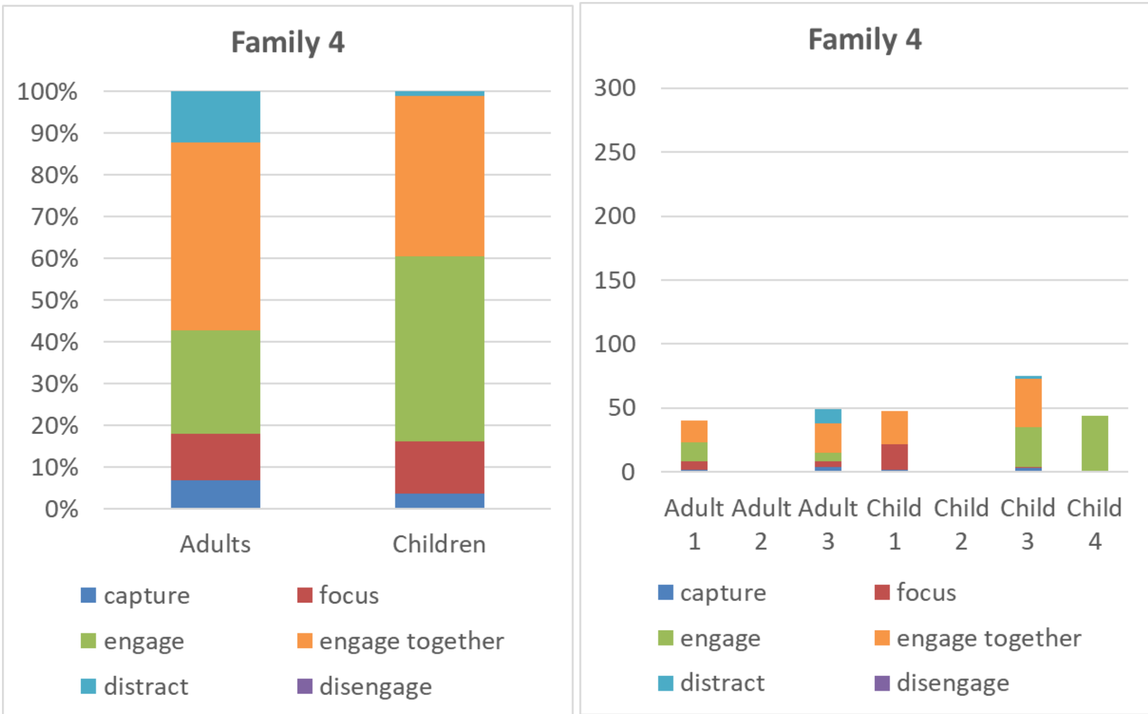



*Figure 6.47 Percentage of adult time and children time spent in each state of engagement by family 4 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

This family has 5 members: two adults and three children. One child starts playing with the exhibit and is followed by one adult and a second child. The two children play with the exhibit together while the first adult carries a tablet with the app already launched and uses it to scan the exhibit QR code, then plays with the exhibit along with the children. The third child leads the second adult to the exhibit and joins the others in playing with the ball, while the second adult is watching them.

A few seconds later the first adult focuses on the app and approaches the second child who has also shown an interest in the app, while the other two children continue to play with the exhibit and invite the second adult to join them. The second adult stands near the exhibit, talks with the children who play with the ball, reads the text panel and points at the panel to attract the children's attention to it, however the children continue their play while the adult continues reading. Meanwhile, the adult and child who were engaging with the app finish using and leave the exhibit. The other family members then follow them.

This family was good at playing with and learning about the exhibit together. They spent around 75 seconds with the exhibit. The two adults seemed to support and encourage the children by talking with them and engaging them with the material on the app and on the text panels. Their visit is a mix of interactions: among family members, with the interactive exhibit, with the app, with the surrounding interpretive media (text panels).

**<u>Group E Family 5: The informative adult</u>**

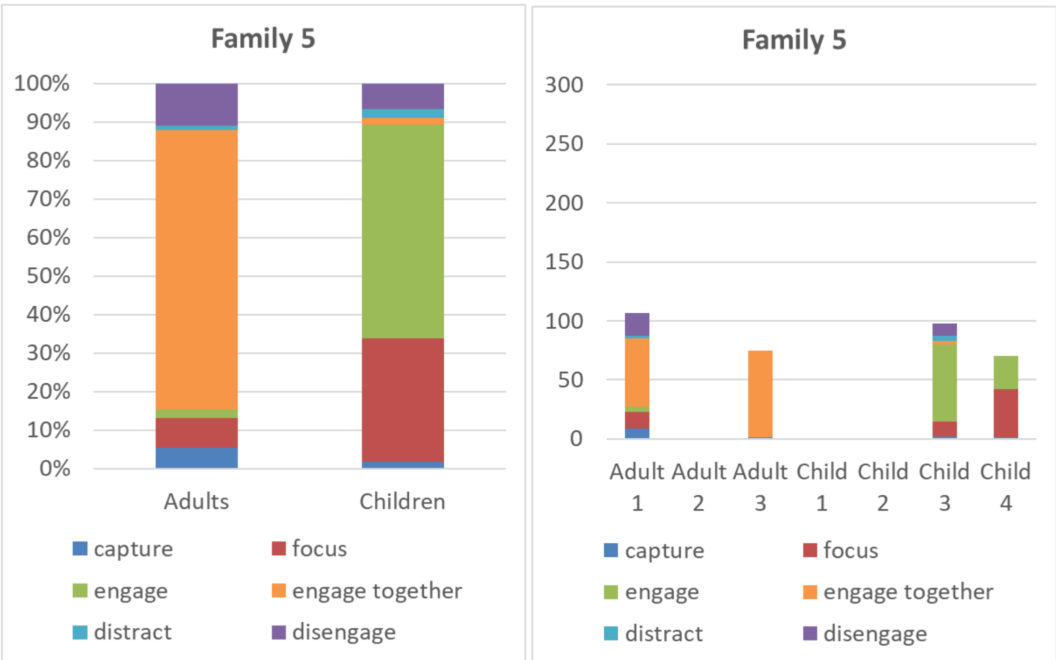
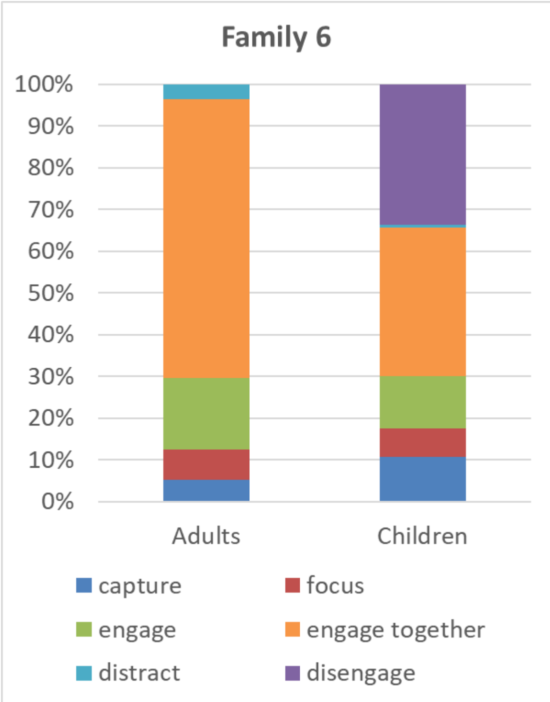



*Figure 6.48 Percentage of adult time and children time spent in each state of engagement by family 5 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

This family consists of two adults and two children. The first adult approaches the exhibit with the mobile device in hand. After a quick glance at the text panel, the adult uses the phone to scan the QR code then calls one of the children and the second adult to the exhibit while starting to experiment with the Plasma ball. The child arrives first and starts exploring the ball and playing with it together with the first adult. The second adult also approaches and talks with the family for approximately 40 seconds, with the first adult often pointing at the ball and apparently offering explanations. A second child comes running, immediately touches the ball and observes the reaction, while the rest of the family are still engaged in play and discussion. There seems to be litter spark with electric discharge from the plasma so the second child stops and looks at the ball while watching the rest of the family's interactions with it. At this point, a third visitor that seems to be unrelated to this family approaches to scan the QR code, then leaves. The arrival of another visitor causes the first adult to step back and move away from the exhibit. The first child also stops playing with it and follows the first adult while the second adult and the second child remain at the exhibit, continue playing with it and engage in conversation for approximately 20 seconds. The other two family members return and the whole family spends time playing with the ball and interacting with each other for another 25 seconds. The two adults then move away from the exhibit and the two children soon follow them.

This family spent a while talking to one another at the exhibit. It was the first adult who used the app and encouraged the others to observe and experiment with the exhibit, providing them with explanations along the way. For this family, the mobile application functioned as a tool for the adult to explain the exhibit to the children so that the whole family could engage with the exhibit.

**<u>Group E Family 6: Engaging, playing, supporting</u>**



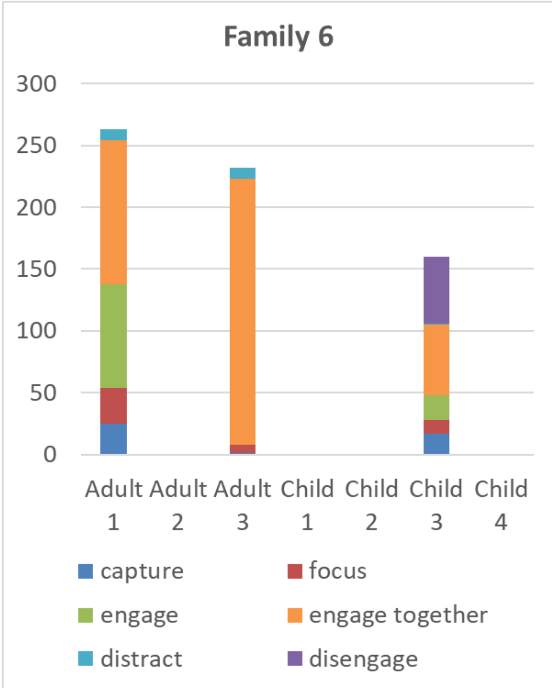




*Figure 6.49 Percentage of adult time and child time spent in each state of engagement by family 6 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

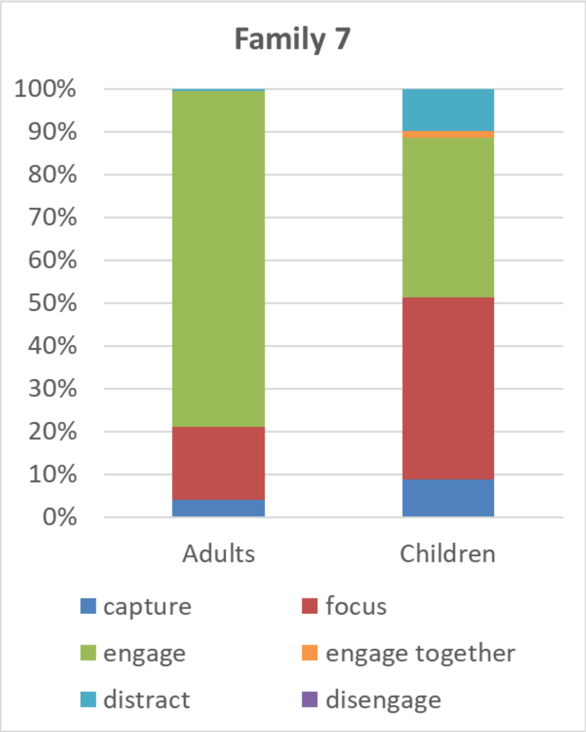
This family comprises 3 members, two adults and one child. The first adult approaches then stops and looks at the exhibit from a distance while another family (one adult and a child holding hands with another adult) is playing with the exhibit. After the other family leaves, the first adult approaches the exhibit and starts playing with it. A few seconds later, the second adult, who is carrying a tablet with the app, and the child join in. The two adults start using the app and talking with each other at the exhibit.

Meanwhile, the child begins experimenting with the ball, playing with it for around 20 seconds without paying attention to the two adults, then looks away and leaves. The two adults are still exploring the app and discussing and the child returns occasionally to briefly play with the exhibit. One minute later, the child is back at the exhibit and approaches the adults and asks to join them in using the app. The family all use the app together and talk about the exhibit. The child looks interested while listening to the adults and looks at the ball.

Meanwhile, another family comes to play with the exhibit, photograph it and leave. Then many groups of students and families approach and play with the exhibit so the family decide to move away from the exhibit. However, both adults continue showing and explaining to the child the information on the app so the child has time to return to the exhibit and look at the app with the family for another 70 seconds before disappearing from the video recorder's viewfinder.

Similar to many other families, it was a parent who used the application while the child was more excited about the interactive exhibit. In this family, the parents continuously engaged with the app so their child had more time to re-engage with the exhibit and check out the app several times. Although the large number of other visitors limited the family's access to the exhibit, the app was nevertheless a useful tool for the family to gain more information. It also allows them to engage with the exhibit indirectly, via engaging with the app, while other visitors are interacting with the exhibit.

**Group E Family 7: the engaged, the toddler, the supporter and the app master.**



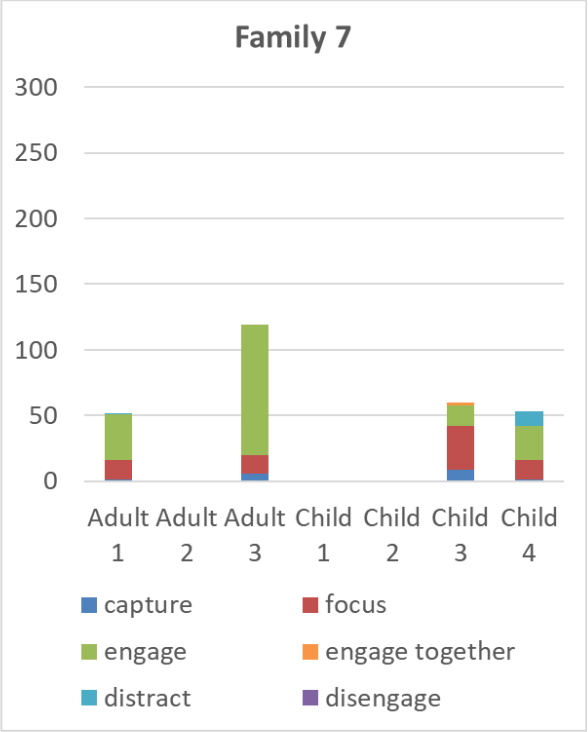




*Figure 6.50 Percentage of adult time and children time spent in each state of engagement by family 7 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

This is a family of 4 consisting of two adults and two children. The older child approaches the exhibit first, points at and touches the ball. The child is joined by another family in playing with the exhibit. A few seconds later, the second child (toddler) runs to the ball and touches it. An adult follows the little child whereas a second adult, with a tablet in one hand, stands behind the group watching the others who are playing with the exhibit.

The two children and the first adult play with the exhibit for about 20 seconds, alongside the second family. Then the older child turns around and takes the tablet from the adult, brings it to the exhibit, scans the QR code and starts using the app. The second adult is still watching the family and the exhibit from the back while the first adult is looking after the little child and plays with the exhibit and reads the panel.

Another group of children joins in and the exhibit becomes quite crowded. This prompts the older child to step back after using the app for approximately 16 seconds, so that other visitors can approach and play with the ball. The child then leaves.

The young child and the first adult are still at the exhibit and experiment with the ball alongside the other family for another 30 seconds, then the young child steps back and runs away from the exhibit. The first adult and the older child follow the little one, but the second adult stays nearby the exhibit alongside the other family, observing the exhibit for approximately 20 seconds. As there is more room at the exhibit following the rest of the family's departure, the second adult then approaches the ball and briefly experiments with it for approximately 10 seconds, then leaves.

This is another family in which a child used the application. The older child used the tablet and engaged with the app on their own, allowing one adult to look after the younger child and the other adult to engage with the text panels – similar to group E family #3. It is important to note here that the child who was using the app appeared familiar with the technology and able to use the app effectively as well as interpret information about the exhibit on their own. Importantly, the app offered an important alternative route to engagement for what was a very crowded exhibit.

**<u>Group E Family 8: Too many people there</u>**

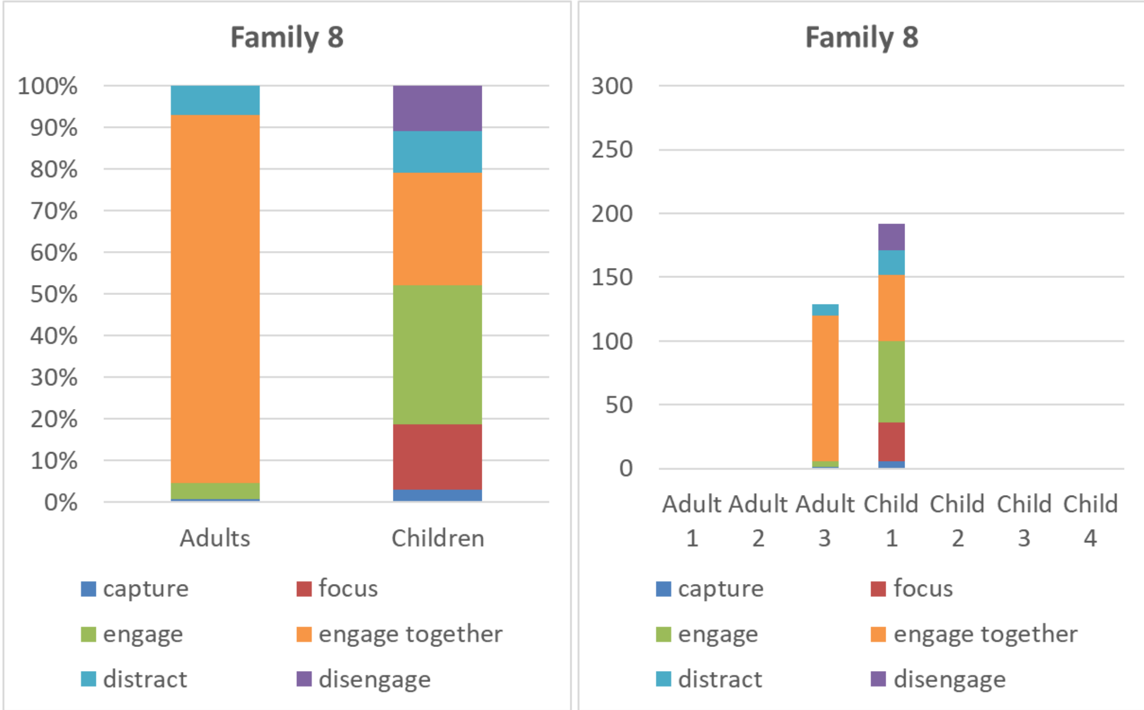


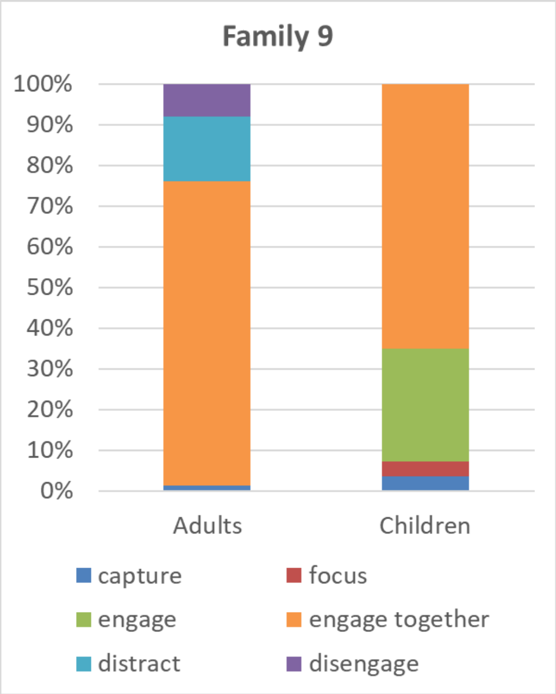

*Figure 6.51 Percentage of adult time and children time spent in each state of engagement by family 8(left) and amount of time (in seconds) each member spent in each state of engagement (right).*

One child approaches and stops to observe the exhibit from a distance while another family group of 5 are playing with it and taking photographs. The child looks at the children playing and waits for an opportunity to come closer to touch the ball. The child also talks with an adult who has arrived and stands nearby. The child looks at the ball and talks with the adult for about 30 seconds but the exhibit is still full of visitors. After that, the child gradually moves through the crowd to the QR code and takes the phone out to scan it. At the same time children from the other family start to leave the exhibit.

The child begins to use the app and the adult steps closer. After finishing using the app, the child returns to the exhibit, talks to the adult and reads the text panel for almost 30 seconds. During that time, a number of visitors walk back and forth to the exhibit so the child and the adult decide to step back. About 20 seconds later, the child returns to the exhibit with which another family is now playing. The child scans the QR code again and steps back to take a photograph of the exhibit, then uses the app for about 15 seconds before leaving.

The benefits of having an app to accompany an exhibit that is popular among visitors were again clear for this family. The child waited to play with the exhibit but hardly had a chance to approach it and would have had no access to the exhibit at all had it not being for the app. It can therefore be argued that the app helps to fill in the gaps left by overcrowded exhibits, enabling families to access the exhibit and initiate conversations among them while waiting for their turn to interact with the exhibit.

**<u>Group E Family 9: The app as stimulus for experimentation and discussion</u>**



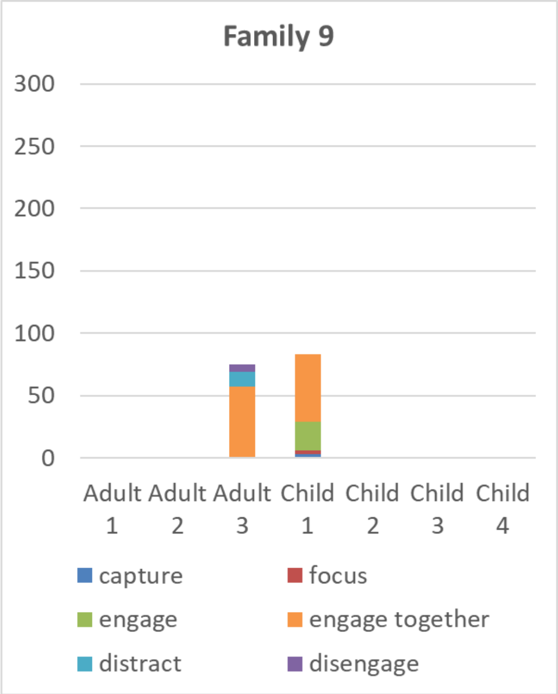




*Figure 6.52 Percentage of adult time and child time spent in each state of engagement by family 9 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

A child approaches the exhibit with a tablet in hand and starts experimenting with the ball, while an adult joins playing with the Plasma ball and talking with the child. A few seconds later, the child uses the tablet to scan the QR code and launches the app while still talking with the adult. They both play with the exhibit and discuss for around one minute before another adult visitor approaches. Then the child and the adult step back but spend another 20 seconds looking at the ball and reading the text panel before leaving. The family spends about 80 seconds at the exhibit together. The arrival of other visitors distracts them from the exhibit.

This family used the application by looking at the information together only at the beginning of their dwell time. The family's engagement involved mostly conversations with each other and playing with the exhibit together. Thus the app was only a tool that stimulated discussion and experimentation with the exhibit.

**<u>Group E Family 10: the return of the app user</u>**

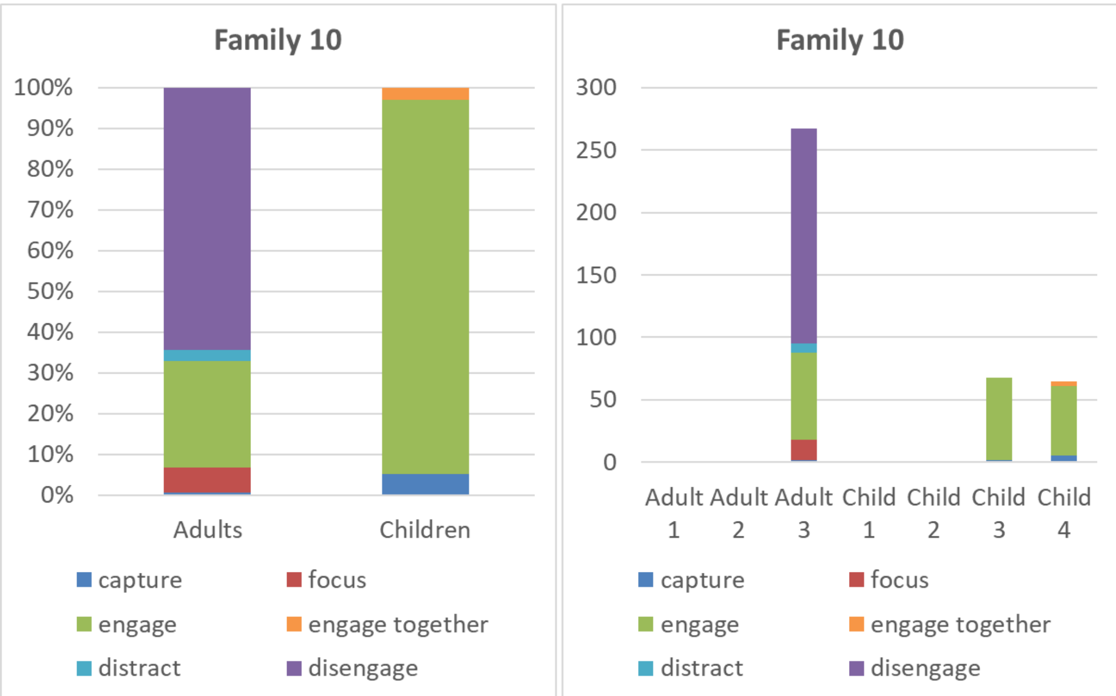



*Figure 6.53 Percentage of adult time and children time spent in each state of engagement by family 10 (left) and amount of time (in seconds) each member spent in each state of engagement (right).*

A child arrives at the exhibit with which another family is playing and taking photographs. The child invites their family to approach the exhibit and touches the ball with a hand. Upon arrival, the second child stands back and watches the first child play with the exhibit. A few seconds later, an adult approaches the exhibit while the other family is leaving. The adult, who is carrying a phone, scans the QR code and starts using the app whereas the first child plays with the exhibit. The second child also steps closer to the exhibit and plays with and talks with the first child.

The adult uses the app while the two children are still at the exhibit for about 50 seconds. Then the first child stops and turns around to take the phone from the adult, and uses the app for 10 seconds. The second child still plays with the exhibit and talks with the first child and the adult. A few seconds later, another family approaches the exhibit so the first child and the adult leave, followed by the second child. Almost 3 minutes later, the adult returns to the exhibit alone and uses their phone to scan the QR code again and spends about 20 seconds using the app before leaving.

In this family, the adult was the app user and shared it with the first child. However, the second child spent most time engaging with the exhibit and talking to the family.

### 6.5.6 Summary of group D and group E family behaviours

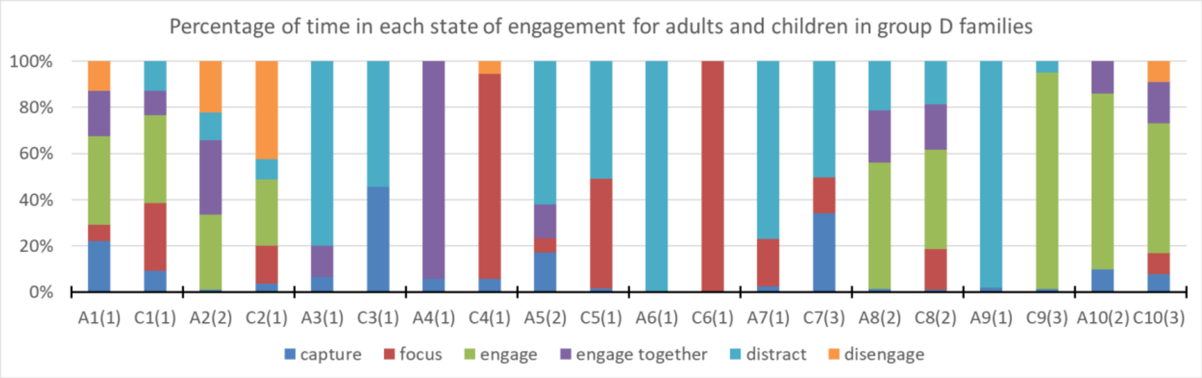
Table 6.8 below gives a brief outline of the twenty families' behaviours.

<u>Table 6.8 Outline of the twenty families' behaviours</u>

| | | |
|---|---|---|
| 1 | Adult captures and focuses child's attention, but then moves child on without allowing opportunity to engage. | Adults using the app nearby leave children space to engage with the exhibit, then they all join together to share the app and interact with the exhibit together. |
| 2 | Young children engage, but only while adults engage with them. | The app may interest only one of the family, but if that person then engages with the family, they can 'transfer' their learning to the group. |
| 3 | The presence of other visitors may cut the visit short. | The presence of a very young child and an adult absorbed by text panels leave older child engaging with the app. |
| 4 | It is hard for an adult with a toddler/baby in arms to engage a child for a sufficient amount of time. | It is possible for a family to interact at many levels: with each other, the exhibits, the app, the surrounding interpretive media (text panels). |
| 5 | Taking photos of text panels may indicate intention to engage post-visit. | The app seems to empower the adult to explain the exhibit to the children. |
| 6 | If the adult's attention is not captured, the child's attention is less likely to be captured. | The app can be a useful proxy to the exhibit when the exhibit itself becomes too crowded. |
| 7 | Some families are there for the 'selfies' – engagement is secondary to photo-capturing the shared experience of their visit. | The app as proxy to crowded exhibit for a child who is not interested in reading text panels. |
| 8 | Some families are there both for engagement and for photo-capturing the shared experience of their visit. | The app as proxy to a crowded exhibit. |
| 9 | Video-recording the experience may prompt a performance which, nevertheless, results in engagement. | The app was used at the start, to stimulate discussion and experimentation with the exhibit. |
| 10 | Family interactions can move swiftly from individual to group interactions. | The app gives alternative means of engagement for those family members who are less inclined to interact with the exhibit. |

This part of the summative evaluation aimed to capture and analyse behaviours of family visitors to the Science Museum. The video-based observation focused on behaviours and interactions between family members as well as their interactions with the exhibit and the mobile application. The two participant groups, D and E, comprised families who did not use the app and families who did use the app respectively. The exhibit being observed here was the Plasma Ball. These families' behaviours at the exhibit were analysed following Bitgood's (2010) three stages of engagement.

The findings suggest that the mobile app helped family visitors to engage and interact with the exhibit more effectively compared to non-app users. App users, both children and adults, interacted with the Plasma Ball twice as much as non-app users and talked to one another within the family group more than non-app users did. This suggests that use of the app encourages interactions and conversations among the family members. Furthermore, when a family member used the app, others in the family had more opportunities to engage with the exhibit. An overview of the impact of the app can be glimpsed by placing side by side the graphs of groups D and E that show percentages of time that adults and children in families spent in each stage of engagement (see Figure 6.54 below). The predominance of green and purple (i.e. engage and engage together) and the relative absence of light blue (distract) is a clear indication of group E families' levels of engagement. In conclusion, the use of the app by family visitors impacted the family's engagement with the exhibit positively.



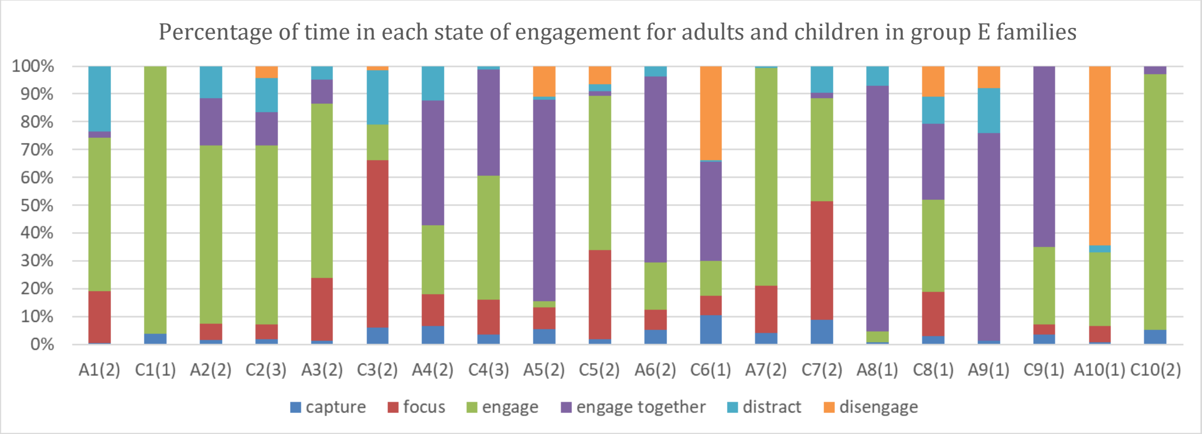




*Figure 6.54 Percentage of time adults and children in group D families (top) and group E families (bottom) spent in each stage of engagement.*

# CHAPTER 7 : DISCUSSION, CONCLUSION AND RECOMMENDATIONS

## 7.1 Introduction

This research sought to identify and capture the impacts of mobile support tools on family learning in the science museum. Through a case study conducted at the National Science Museum in Thailand, which involved the development and evaluation of a mobile app with family groups, the research addressed this question as well as the related sub-questions of how these impacts could be identified and captured, and how we can best design for these impacts in other museums and informal science learning environments. This chapter discusses our findings, identifies the limitations of this research and makes recommendations for future research in the area of family learning in the science museum.

## 7.2 Identifying and capturing impacts on family learning

Addressing the main research question required to first address the question of how can we identify and capture impacts on family learning: given the difficulties in capturing and measuring learning in the museum discussed earlier in this thesis, how can we identify the impacts on family learning of mobile learning tools that are aimed to support family visits to science museums? Although this research cannot give a definitive answer to this question, it can nevertheless give one possible answer, which is implied in the research methodology discussed in Chapter 3.

In essence, the methodology combined evidence in families' post-visit accounts of their visit experience with evidence of families' behaviuors and interactions observed in video recordings. Importantly, the two kinds of evidence validated each other, while providing a more robust and complete picture of the family visit.

The three analytic frameworks of museum learning – the Contextual Model of Learning, the Generic Learning Outcomes, and the Attention-Value Model of Visitor Engagement – were key in both planning for the collection of, and in the interpretation of this evidence. We found the Attention-Value Model of Visitor Engagement, in particular, central to the interpretation of observational data of family behaviours. Our observations showed that one more state of engagement comes into play in family visits, that of 'distracted' attention. This is distinct from the 'capture', 'focus' and 'engage' states described in the model, and is also distinct from the disengagement at the end of a person's interactions with an exhibit. Its distinctiveness comes from the fact that, while it represents a temporary pause in engagement, the person can potentially return to capturing and focusing their attention back on the exhibit. Further research is needed to clarify whether this is a distinct state for family groups, and what are its impacts on the person's / family's learning, particularly how it correlates with longer dwell times and the presence of more intense engagement periods.

The Generic Learning Outcomes is a well-established framework for capturing the breadth and depth of learning outcomes in museums. It therefore both guided data collection, and enabled an analysis that exposed the strengths and weaknesses of the app across the range of these outcomes.

The Contextual Model of Learning played a more subtle role in the design and conduct of this study, by helping us focus on the special importance of the Personal and Sociocultural contexts and their interplay with the Physical context of the exhibition. In this study, it emerged that the Family context plays a particular role in bringing the Personal and Social contexts together, as the family itself has contributed greatly to these two contexts.

Finally, the summative evaluation emphasized the importance of assessing the potential impact of usability on the family experience. Usability is typically considered a property of the product that can make it or break it. When the focus of the evaluation however is more on the experience that is facilitated by the product rather than the use of the product itself (as was the case in this study), there is a real danger that usability problems might be overlooked while having a detrimental impact on the family learning experience. It is therefore important that, before an evaluation of the learning experience, the usability of the tool has been assessed and any major usability issues have been addressed (Vavoula & Sharples, 2009).

## 7.3 Impacts of mobile learning tools on family learning in the science museum

**The value of interactions for the family**

The study showed that interactions are a highly valued element of the family visit. Exhibits that can be interacted with by engaging senses and modalities beyond vision are more popular with families, i.e. exhibits that can be manipulated, handled, exhibits whose behaviour or state can change with visitor action. In this study, families gave next to zero responses to the static Camera exhibit in the showcase. My own experience, as staff in the museum, says that the most popular exhibits are interactive. There is a certain sense of enjoyment that comes from multimodal experiences that engage more than one senses (Allen, 2004), and that enjoyment leads to more focused engagement and learning (Bitgood, 2010).

Families also value interactions amongst themselves. The family visit is primarily a social experience (Ash, 2003; Blud, 1990; Diamond, 1986; Falk & Dierking, 1992, 2013; Hilke, 1989; Hooper-Greenhill & Moussouri, 1999). Families in this study showed clearly this to be the case, placing their 'togetherness' higher on their visit agendas than science learning.

The app has successfully amplified both these types of interactions. By directly referencing the interactive exhibits, offering visitors instructions and guidance how to use them and assisting them to interpret the outcomes of their interactions with the exhibits, the app has intensified the visitors' use of the interactive exhibits. At the same time, the app is providing families something to talk about: the app becomes the focus of joint family attention when family members come together to watch a video or demonstration, or listen to a narrated story. It thus also becomes a tool for families to interact with each other meaningfully, by empowering parents to explain the museum to their children.

In doing these, the app itself becomes a type of interaction: whether using it together or used by the 'explainer' in the family, the app is another 'thing' in the museum environment that families can interact with. Thereby the app adds to the family's active engagement with the museum context. Both constructivism and discovery learning emphasise the role of active engagement with learning material and activities (Bicknell-Holmes & Hoffman, 2000; Castronova, 2002; Hein, 1991, 1998, 2000), therefore it comes as no surprise that increased interactions then lead to more learning.

## The value of exhibition aids for families

Science museums are usually filled with interactive displays, which encourage visitors to learn by experimenting and interacting with them. Museum exhibits together with their stimulating environment can well arouse visitors' curiosity and enhance learning experiences (Boyle, 2009; Falk & Dierking, 2000; Hooper-Greenhill, 1994; Pedretti, 2007). This research study found that the mobile application can also be used as an effective aid for families in exploring the museum, engaging and experimenting with the exhibits as well as gaining further information about the displays.

Families with the mobile application, when arriving at the exhibit, were able to rapidly focus their attention on the exhibit and remain concentrated for a longer time compared to the non app user family (see video-based observation findings in Chapter 6). The findings also demonstrate that the use of the application slowed the families down, giving all the members more time to engage with the exhibit and with one another while being less distracted.

The video-based observations revealed a 50 second adult engagement rule for children's engagement: when the adult spent over 50 seconds engaging with the exhibit, children in the group tended to also focus their attention and engage. With the app extending adult engagement well beyond the 50 seconds milestone, children in families who used the app were more likely to engage too.

Engagement with the app was not at the detriment of engagement with the exhibit, however. On the contrary, although when looking at app users the app seemed to occupy family members more than the interactive exhibit, their interactions with the exhibit itself were in fact longer than those of families who were not using the app. So far from weakening interactions with the exhibit, the app instead significantly increased family dwell time.

The findings here support Falk and Dirking's (2008) argument that digital media can aid visitors, medias they have the potential to initiate interactions and enhance learning as long as they are designed to suit the visitors' interests, motivations and their prior experiences in order to awaken their intellectual curiosities. In this case, the app worked in-sync with the other interpretive elements of the exhibit and with the exhibit itself, as it was referencing the information in the text panels, providing instructions how to use the exhibit, and providing interpretations of the family's interactions with the exhibit.

**<u>Support for learning through seamless integration with other interpretive media</u>**

Within the museum gallery, families experience the physical context that is made up from the text panels, the interactive exhibit and other interpretative media and apparatuses. Previous research shows a lack of attention to those interpretive media from family visitors, as they tend to put an emphasis on maintaining social interaction and enjoyment among the family group (Falk & Dierking, 2013). However, this research found that the use of the app increases both the use of the text panels and their appreciation as learning aids. The learning needs analysis showed that adults in the family groups found the text panels difficult to comprehend and relay to the children in a way that the children can understand. The design of the app took this into account and provided interpretation that used simpler language – in a sense, the app interpreted the interpretive text panels. This brought the scientific content of the exhibits within the adults' 'zone of proximal development', with the app (and in fact through the app the museum's science communication team) assuming the role of the 'more knowledgeable other'. In some cases, particularly for families with younger children, this in turn enabled the adults in the family group to assume that role of the 'more knowledgeable other' with their children. In families with older children, adults and children inhabited the same 'zone of proximal development' and took turns to interact with the app directly, or used the app together. These behaviours match family behaviours described in previous studies, which reported that families tend to spend most of the time at the exhibition talking, exchanging information with one another and attempting to explain it to one another (Ash, 2002; Callanan, 2001; Crowley *et al.*, 2001; Ellenbogen, 2002; Falk, 1991; Falk & Dierking, 2000; Hilke, 1989; Leinhardt, Crowley & Knutson, 2002; McManus, 1987, 1988; Rosenthal & Blankman-Hetrick, 2002).

As the app facilitates the family's meaning making from the exhibit's interpretive media, the role of interpretative staff, who normally assume this facilitating role, becomes less needed. Indeed, this study found that the app supersedes facilitators as learning aid – unless the interactive exhibit is broken. As the app is designed to make direct references to the interactive exhibit and provide an interpretation of the outcomes of the family's interactions with the exhibit, when the exhibit is out of order this link breaks and the facilitating value of the app diminishes. Human facilitators however adapt their mediation to the circumstances and therefore better compensate for broken interactive exhibits.

The design of the app in this study did not compensate for broken exhibits. This was because broken exhibits did not come up as an issue in the family learning needs analysis, probably because the availability of museum staff was already compensating for broken exhibits. This reveals, on the one hand, the need for a future version of the app to take into account the possibility that the interactive exhibits that is supports might be out of order; and on the other hand the fact that visitor studies for learning needs analysis might not capture all visitor needs. In fact, it may well be the case that the use of the app has revealed to families the detrimental impact of broken exhibits on their visit experience and, thus, altered the needs priorities for family groups. This emphasizes the need for continuous assessment of visitor needs, as these needs are not static but instead evolve and change as the museum's visitor offer changes with the introduction of new learning aids and tools.

A final finding related to how the app works in relation to other interpretive media and elements in the museum, is that families who used the app did not take part in other (interpretive) activities or programmes on offer in the museum. This may have been because the app significantly increased family dwell time and, therefore, left families with less time available to take part in such activities. Alternatively, it may be that families who opted to take part in the app trial were those families who were not planning to take part in other activities or programmes. In either case, whether filling in a gap for those families who were not interested in organized activities or offering similar levels of engagement as organized activities, the findings do not suggest that the families saw this as a weakness or that there was any direct competition between the app and other interpretive activities.

**Support the experienced and the inexperienced family group**

This research study found that the app increased learning outcomes more for repeat visitors who seem to seek more unconventional interactions – something different that they have not seen/done already in a previous visit – and stimulates these families to talk more with each other about the exhibit. First-time visitors have a lot to absorb already: the museum space, the exhibits, the other interpretive elements. But families who have been to the museum previously are already familiar with the space and are likely to have interacted with the exhibits before. For these families the app acts as a reminder and helps them further develop their understanding of the information they encountered previously, as well as presenting them with new interpretive content – not least, a newly presented interpretation of the outcomes of their interactions with the exhibits. The app therefore offers these families something new to interact with and around, a new focal point for their interactions.

By contrast, families who are visiting for the first time are preoccupied with making sense of the environment. Previous research suggests that first-time visitors tend to learn by watching and imitating other visitors (Koran *et al*. 1988, cited in Falk & Dierking, 2013). For these families the app may be another aspect of the museum environment that they need to make sense of. This preoccupation with orientating themselves within the context of the museum seems to limit the learning impact of the app on first-time visitors. The overall positive feedback from families who were first-time visitors, however, suggests that the app still has a place as interpretive tool for this group, namely to help them become familiar with the exhibit, thus paving the way for the deeper learning experiences that follow in repeat visits.

The benefits of the app for repeat visitors however extend beyond learning gains. Additionally, the study finds that the app enabled repeat visitors to engage with the museum as a playful, fun and cognitively accessible science learning environment. It might be argued that the first visit makes subsequent visits easier and more enjoyable, as families are able to engage with the exhibition more confidently. However, the repeat visitors in the app user group seem to get much more enjoyment out of their visit than repeat visitors in the non-user group, which suggests that the app further enhances the effects of prior visits.

## Enjoyment of and attitudes towards science and the science museum

One of the families' expectations from museum visits is to spend leisure time with one another (Falk & Dierking, 2013) while one of the most popular environments for science learning outside the classroom is the science museum. Informal science learning not only enhances understanding of science but also should provide enjoyment to visitors (Fenichel & Schweingruber, 2010).

In this research study too, spending leisure time together featured heavily in the family visit agendas. Families also expected to gain more scientific knowledge, however, enjoying their leisure time together was higher on family agendas than learning. Importantly, the use of the mobile application seems to have increased family enjoyment: using the app is itself an enjoyable activity, while the fact that the app is directly referencing the interactive exhibits and facilitates family interactions with them also increases the enjoyment of the interactive exhibits themselves.

Additionally, integration of the app in the family experience results in increased interest in science. It appears that the scientific content and media in the application can make science more interesting for the app user families. It also appears to arouse curiosity and interest, as app users seem to leave the museum with the intention to use the app again, thus indicating an intention to construct a science learning experience to follow up their visit. Key to this seem to be the multimedia content and simple (yet scientific) language of the app that make science content more interesting and less alienating, particularly for young family members. So the app develops positive attitudes towards science, making it seem more accessible and easier to understand.

What is more important is that the families' enjoyment from the application also leads to positive attitudes towards science. In this study, the families regarded the science museum as a place for family members to spend leisure time together, but also provided a good environment for informal science learning. Such findings are in agreement with Ash's (2003) argument that families tend to use the museum as a place where they can enjoy learning and interactions with one another.

This research also finds that the app marks the experience of repeat visitors enough to make the visit worth talking about to friends and families. It can therefore be concluded that the mobile application designed for the science museum in this study has potential to positively change family attitudes or values. The evidence of enjoyment can also be viewed as a significant outcome for informal science learning settings (ECSITE, 2008).

**Family behaviours at exhibits**

Observations of family behaviours at the exhibits showed that the app results in a 'break up and rejoin' approach to the construction of the family itinerary in the museum. Individual family members were observed to break away from the family group and rejoin, either following their own personal interests or following clues from other family members – for example, a parent might call a child back to show them something about an exhibit (rejoin), or a parent might follow a child whose attention has been drawn to another exhibit (break away). These patterns, however, had far from a negative impact on family dwell time, which was significantly higher for families who used the app. In fact, use of the app seems to have freed individual family members to follow their own interests (Dierking, 1989) while at the same time extending the family's overall interaction with the exhibit. Idle time of family members who wait for other members e.g. to 'be done' with the app was therefore reduced, while these family members who stayed back seem to have attracted those who were not to rejoin and re-engage. This was a distinct behaviour of app family users, and may well be the reason behind the app's positive learning impacts.

## 7.4 Design for positive learning impacts

The design of the app for the National Science Museum was based on a design framework that was constructed based on a study of family learning needs, following an iterative development approach. The design framework highlighted certain requirements, like the use of simple, understandable scientific language, the provision of high quality content, and the provision of support for interacting with exhibits. Evaluation findings point towards further additions to this design framework.

The first recommendation regards the cross-referencing between the app and other interpretive elements of the exhibits. The evaluation showed that families who used the application showed more interest in reading the text panels and attempting to engage with other interpretive elements of the exhibit. This was a result of the app cross-referencing these other interpretative elements in the exhibition. This was achieved by the app providing content that spoke directly to the text panels, e.g. presenting the complicated information that was on the text panels using simpler language. It was also achieved by speaking directly to the interactive exhibit, e.g. giving families instructions how to operate and use it, and also helping families interpret the outcomes of their interactions with the exhibit. Such cross-referencing further enhanced the learning outcomes for families, through providing information with different levels of complexity and language suitable for target audiences. In addition, cross-referencing increases the coherence and unity of the information presented on different media, giving a connected experience across the physical space of the exhibit and the ‘virtual’ space of the app.

A second recommendation regards the choice of media. In this study, families used the video, audio and text that were available on the app. Video appears to have been the most popular medium amongst families, followed by text, followed by audio. Problems with background noise in the exhibition may have pushed audio to the bottom of the families’ preference list, reinforcing the need for media choices to be made with regard to the specifics of the physical environment where they are meant to be used. Understanding the conditions under which each medium is best consumed, and choosing media in accordance with the conditions present at each exhibit, is essential for the success of any mobile learning system that is location-aware. Video in this app presented graphic animations of scientific phenomena that are generally difficult to observe with a naked eye, such as the reflection of sound waves at the Whisper Dishes exhibit. In such circumstances the choice of video is not only convenience, but is essential for conveying such science content in a format that complements text. The use of a variety of media in the app helped the users to better understand and have more confidence in their interactions with the exhibit, which in turn resulted in a more effective learning experience.

A final recommendation comes from a finding discussed earlier in this chapter, namely that as the app facilitates interactions with interactive exhibits, it is more noticeable when these interactive exhibits are out of working order. If the interactive exhibits are broken and the app is trying to facilitate interaction with them, visitors end up more dissatisfied than if they were not using the app. This suggests that maintenance plans need not only ensure regular and frequent maintenance of the interactive exhibits, but may also include back up interpretation in the app to compensate for broken exhibits during maintenance periods.

## 7.5 Concluding remarks

This study has shown that a mobile app, when designed in accordance with family needs, can be an effective tool for the facilitation of family learning in the science museum. Enhanced learning outcomes from the use of the application in the museum is evidence of its capability as a tool that facilitates learning. What is also important, is that many families in the study intended to continue using the application after they returned home in order to learn more. This significant indication of post-visit learning and engagement is worth following up in future research: a longitudinal study with families who use the app could help shed light on longer-term impacts on family science learning, while comparisons with families who do not use the app can help us understand the magnitude of such impacts.

Further research is also needed to follow up the differences identified here between first-time, occasional and repeat family visitors. An ethnographic study of families who visit for the first-time and then make repeat visits can help us further nuance how family needs evolve with every visit and, thereby, help us design mobile tools that adapt to these evolving needs.

One major limitation of this research is the low numbers of participants in the summative evaluation activities. A larger number of families in the two video-based observation groups would have allowed for statistically verifiable conclusions regarding differences in dwell time and states of engagement; as well as a more nuanced translation of Bitgood's attention-value model of engagement for use in the analysis of observational data.

This study was conducted in the National Science Museum in Thailand, a country that has not featured so far as context in the museum science learning literature. While findings are aligned with museum learning literature originating in the West, a comparative study in other contexts could shed light on how culture impacts family behaviours, interests and priorities in the science museum, and how it impacts the effectiveness of mobile family learning tools.

Like any other visitor group, the family group comprises individuals with distinct needs, abilities and prior experiences. At the same time, however, the family context means that these individuals share a history of interactions that have, to an extent, shaped these individual contexts. The family interactions in the museum are enmeshed in that history of interactions and, thus, the family visit becomes part of the family identity. Museum experiences can therefore be more than just learning experiences for families, they can become part of what defines a group of people as a family. This study has shown that mobile tools can play an integral part in this process, by encouraging more, and higher quality family interactions.

# Apendices

## Appendix 1 Ethics Review Document

University of Leicester Ethics Review Sign Off Document

To: **WIJITRA SURIYAKUL NA AYUDHYA**

Subject: Ethical Application Ref: **wsna1-5a37**

*(Please quote this ref on all correspondence)*

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**11/09/2012 13:08:51**

**Museum Studies**

Project Title: **Mobile Learning meets Family Learning in the Science Museum: A Case Study of Family Science Learning in the National Science Museum, Thailand**

Thank you for submitting your application which has been considered.

This study has been given ethical approval, subject to any conditions quoted in the attached notes.

Any significant departure from the programme of research as outlined in the application for research ethics approval (such as changes in methodological approach, large delays in commencement of research, additional forms of data collection or major expansions in sample size) must be reported to your Departmental Research Ethics Officer.

Approval is given on the understanding that the University Research Ethics Code of Practice and other research ethics guidelines and protocols will be compiled with

- http://www2.le.ac.uk/institution/committees/research-ethics/code-of-practice
- http://www.le.ac.uk/safety/

University of Leicester

# Appendix 2 information sheet for participants

**Information Sheet for Participants**

Project Title: Mobile Learning meets Family Learning in the Science Museum: A Case Study of

Family Science Learning in the National Science Museum, Thailand

Contact Address: [redacted]

Email: wsna1@le.ac.uk

Date: 29 July 2012

**Dear Sir/ Madam,**

I am very grateful that you are willing to take the time to consider participating in my research project 'Mobile Learning meets Family Learning in the Science Museum: A Case Study of Family Science Learning in the National Science Museum, Thailand'. I would like to take this opportunity to tell you more about the nature of the project, who I am and why I am undertaking this research, and how you were selected for the project. I would also like to inform you about how the data you supply to me will be used and the protections of your privacy and confidentiality that are in place.

***Who is doing the survey***

My name is Wijitra Suriyakul Na Ayudhya, I am a postgraduate research student in Museum Studies at University of Leicester. Today I have Mr. Chanin Suriyaku Na Ayudhya, a science communicator at the National Science Museum Thailand, conducting the interview on behalf me on part of my PhD research.

***What is the project/survey for***

The aim of this research is to develop a better understanding of 'How can science museums in non-Western contexts increase their impact on family audiences through the use of mobile technologies? In this preliminary research I am looking at what are the current learning impacts and what are the desirable learning impacts of Thai family visits to Science Museums'.

***How you were selected***

This part of the research involves interviewing families that visit the museum (parent and child(ren) aged between 6-12). Your family was selected because you are the first family to enter the museum after the previous interview was completed.

***Your role in completing the project/survey***

Your family will be given an explanation about the detail of the research and you will receive research information sheets for parent and child(ren). In this regard, please take your time to read through the information sheet and/or have a conversation with each other to decide whether you would like to participate. In case any of you have any questions please feel free to ask me. Each member of your family will then be asked to consent to participate in the study by signing a consent form. We will need all members of your family to consent in order for your family to be able to participate. Your participation involves an interview, which will take place after you have finished visiting the gallery. The interview will take place at the meeting area, which is in front of the escalator on the fourth floor of the museum. The interview will last approximately 20 minutes. During the interview, all the family members are encouraged to participate and share their opinions. There is no right or wrong answer to the questions. To facilitate data analysis, the interview will be audio-recorded and I will also be taking notes by hand. The data will be anonymised before it is analysed and published and care will be taken so as no family member can be identified in the written reports. All material and information collected will be kept safe, according to the UK Data Protection Act 1998 (see http://www.legislation.gov.uk/ ukpga/1998/29/ contents).

***Your rights***

Your participation in this research is entirely voluntary and you are free to withdraw from the project at any point until December 2012. If you are uncertain or uncomfortable about any aspect of your participation please contact me to discuss your concerns or request clarification on any aspect of the study.

***Protecting your confidentiality***

Any information you supply will be treated confidentially. After the interviews data will be digitized and encrypted by the interviewer and sent to me via email.

If you have any questions about the ethical conduct of the research please contact the School

Research Ethics Officer, Dr Giasemi Vavoula[redacted] Thank you very much for your consideration,

With best wishes,

<SIGN>

Ms.Wijitra Suriyakul Na Ayudhya

# Research information sheet for Child(ren)

"Hello, my name is Chanin Suriyakul Na Ayudhya. I am doing the interview for a PhD researcher who are trying to find out all about what is children think about Family learning and mobile learning in a Science Museum and what are the problems and what are the need of the family? I would like some children in a family group help me by talking to each other with your parent and answering me about 10 questions in about 20 minutes long. Your parent/s will be present all the time. While we are talking I will record it on my sound recorder so that I can listen to it again. There is no right or wrong answer for my questions so please feel free to add you comment and idea and if you don't want to answer some of the questions that is okay. If you don't want to talk to me today you won't get into trouble. Anytime you want to stop talking that's okay and I will turn the tape off. Your real name will notbe seen by other people except the people do this research.

The tape and copy of your words from the tape will be kept private. If you have any worries about our talk then you can talk with me about that.

Thank you very much for your consideration.

<Sign>

Chanin Suriyakul Na Ayudhya

DATE: …………………………………..

# Appendix 3 Interview question for the family learning needs analysis

## Questions for interview

**Group 1 Family visitor between 7-10 groups**

### Part 1:

1) What is your purpose to visit the museum today, are you visiting specific exhibition? How did your family interact with each other in the gallery? What is your opinion about acquiring or gathering scientific content from the exhibitions? How these experiences happen in the gallery?

2) In your opinion, what is helped and what is hindrance your family from learning today? And is there any kind of problems from your visit today in term of learning through scientific exhibition?

3) What would you like to have seen or done today to enable you to learn better or gain more understanding?

### Part 2:

4) In case of the museum would like to gain more family visitors to visit and discover more about science, could you suggest about what kind of developments or services in the gallery that museum should implement?

5) In your opinion, how science exhibition can be more engaged with the family visitor?

6) In the interest of developing family learning science in the museum, what should the museum do?

### Part 3:

7) Did you take a photo in the gallery? Do you have experiences using mobile technology such as smart phone to collect information or picture from the exhibition? Was it useful? What is your opinion about mobile learning? What is it looks like?

8) In case of the science museum would like to develop the mobile learning system in the museum in order to enhance the family learning experiences in the museum, what would you like to have in this system? What would you expect to be seen in this system?

9) And finally where in the museum you would like to have this kind of service.

Which part or what kind of the exhibition in the museum you would like to use this kind of the service?

University of Leicester

# Appendix 4 Ethics Review Document for the Summative evaluation

University of Leicester Ethics Review Sign Off Document

To: **Ms.Wijitra Suriyakul Na Ayudhya**

Subject: Ethical Application Ref: **wsna1-04bf**

*(Please quote this ref on all correspondence)*

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**07/04/2015 21:49:31**

**Museum Studies**

Project Title: **Mobile Learning meets Family Learning in the Science Museum: A Case Study of Family Science Learning in the National Science Museum, Thailand**

Thank you for submitting your application which has been considered.

This study has been given ethical approval, subject to any conditions quoted in the attached notes.

Any significant departure from the programme of research as outlined in the application for research ethics approval (such as changes in methodological approach, large delays in commencement of research, additional forms of data collection or major expansions in sample size) must be reported to your Departmental Research Ethics Officer.

Approval is given on the understanding that the University Research Ethics Code of Practice and other research ethics guidelines and protocols will be compiled with

- http://www2.le.ac.uk/institution/committees/research-ethics/code-of-practice
- http://www.le.ac.uk/safety/

## Appendix 5 Interview questions for Usability

*PhD research project : Mobile Learning meets Family Learning in the Science Museum: A Case Study of Family Science Learning in the National Science Museum, Thailand*

### *Interview questions*

| | **General information** | | | | | | |
|---|---|---|---|---|---|---|---|
| | How old are you?<br>Father ☐ 20-30 ☐ 31-40 ☐ 41-50 ☐other_______<br>Mother ☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ other_______<br>Other relationship______☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ other_______<br>Child(1)______Boy/Girl, Child(2) _____ Boy/Girl, Child(3)________Boy/Girl | | | | | | |
| | How many members in your group today? | | | | | | |
| | Have you ever been to science museum? /How often? | | | | | | |
| | **The experience of using mobile application in gallery** | | | | | | |
| | **<u>Part 1: The Usability of the mobile app</u>**<br>On a scale from 1 to 5, where 1 is 'strongly disagree' and 7 is 'strongly agree', rate how much you agree or disagree with the following statements: | | | | | | |
| | | Strongly Disagree | | Neutral | | Strongly Agree | |
| | **Usability Scale** | **1** | **2** | **3** | **4** | **5** | **Comment** |
| 1. | I think that I would like to use this system frequently | | | | | | |
| 2. | I found the system unnecessarily complex | | | | | | |
| 3. | I thought the system was easy to use | | | | | | |
| 4. | I think that I would need the support of a technical person to be able to use this system | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5. | I found the various functions in this system were well integrated | | | | | | |
| | | Strongly Disagree | | Neutral | | | Strongly Agree |
| | **Usability Scale** | **1** | **2** | **3** | **4** | **5** | **Comment** |
| 6. | I thought there was too much inconsistency in this system | | | | | | |
| 7. | I would imagine that most people would learn to use this system very quickly | | | | | | |
| 8. | I found the system very cumbersome to use | | | | | | |
| 9. | I felt very confident using the system | | | | | | |
| 10. | I needed to learn a lot of things before I could get going with this system | | | | | | |

| | |
|---|---|
| | **Part 2 : Needs/ Problems and additional desirable of family visit** |
| 11. | Based on your experience, what were the benefits of using the app today? |
| 12. | Based on your experience, what were the problems with using the app today? |
| 13. | In your opinion, what helped your family learn in the museum today? (e.g. discussions within your family, the text panels, handling the exhibits, using the app) |
| 14. | Did your family have any kind of problems that impeded your learning during your museum visit today? |
| 15. | How could the museum improve your family experience and your family's learning in the museum? |
| 16 | **Additional comments and suggestions ( Optional)** |
| | |

## Appendix 6 Interview questions for GLOs

University of Leicester

*PhD research project : Mobile Learning meets Family Learning in the Science Museum: A Case Study of Family Science Learning in the National Science Museum, Thailand*

### *Interview questions Control and Experimental group*

Date: ________________________

Time : start_______end________

*Family using mobile app* ☐ *Yes* ☐ *No*

| | |
|---|---|
| **Section 1 : Entry interview** | |
| **Part 1 General information** | |
| 1. | How old are you?<br>Father ☐ 20-30 ☐ 31-40 ☐ 41-50 ☐other_______<br>Mother ☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ other_______<br>Other relationship______☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ other________<br>Child(1) ______ Boy/Girl, Child(2) _________Boy/Girl, Child (3)_______Boy/Girl |
| 2. | How many members in your group today? |
| 3. | Have you been to the science museum before? / If yes: How often do you visit? |
| 4. | What are you expecting from your visit today? |
| **Part 2 Knowledge about specific contents/ exhibits** ; Asking and using the personal meaning mapping (PMM) and Family meaning mapping activities (FMM) | |
| **Lucy** | |
| 5. | Have you ever heard about the theory of evolution? What do you know about it? What do you know about 'Lucy'? What is your opinion about 'Lucy' and the theory of evolution?<br>The children will be asking the questions and also will be ask to generate the PMM |
| **Plasma Ball** | |
| 6. | What do you know about 'Plasma', and what is your opinion about it? |
| **Camera** | |
| 7. | Do you know how the camera was invented and/or how it works? C<br>Can you tell me? |

| | |
|---|---|
| **<u>Family meaning mapping</u>**<br>family group will be asked to draw a picture / write a word together) | |
| **Whisper dishes** | |
| 8. | Can you explain the reflection of sound? |
| Finish the entry interview and observe the family (behaviour and interaction) in one selected exhibit in the gallery ( the families will be ask to visit the specific exhibits | |
| Exhibit observed:_______________<br>Time finish entry interview :___________Time start exit interview section: __________ | |
| **<u>Section 2 : Exit interview</u>** | |
| Interview about the experiences of the family during their visit with the GLOs framework | |
| **<u>Part 3 Questions to explore Knowledge and understanding</u>** | |
| 9. | What did your family discover today in the museum? |
| Repeat the interview for parent and personal meaning mapping for child(ren) | |
| **Lucy** | |
| 10. | Have you seen *'Lucy'*? What do you know 'Lucy' now?<br>(asking the children to draw / or write) |
| **Plasma Ball** | |
| 11. | Have you played with the *'Plasma ball'*? What do you know about *'Plasma'* now? |
| **Camera** | |
| 12. | Have you seen the camera in the showcase in front of the dark room on the third floor? What do you know about its invention and how it works now? |
| **<u>Part 4 Family Meaning Mapping (FMM)</u>** | |
| **Whisper dishes** | |
| 13. | Have you seen and played with the giant dishes in parabolic shape on the third floor? What did you learn from it about the reflection of sound? |
| **<u>Part 5 Questions to explore Skill</u>** | |
| 14. | Did you learn a new skill or have done something that you never done before today? |

| | |
|---|---|
| **<u>Part 6 Questions about attitudes and values</u>** | |
| 15. | Did the museum visit today change the way you think or feel about a scientific concept or process, or how you view it, if yes how? |
| 16. | Did the museum visit help you enjoy your family, how? |
| 17. | Has your visit changed the way you think or feel about the science museum? If yes, in what ways? (Attitudes toward the museum) |
| 18. | Has your visit changed the way you think or feel about science learning in general, and /or about science learning in your family? |
| **<u>Part 7 Question about Enjoyment, Inspiration and Creativity</u>** | |
| 19. | What did you particularly enjoy today? What is your opinions about your visit today? |
| **<u>Part 8 Question that relate to Action, Behaviour, and Progression</u>** | |
| 20. | What did you do in the gallery? |
| 21. | What, if anything, do you think the young people in your group might want to do as a result of today's visit? |
| **<u>Part 9 Question for summary / Wrap up questions</u>** | |
| 22. | If you could choose just one or two things what would you say was the most important benefit to your family from their visit today? |
| **<u>Additional exit interview questions for the families that used mobile application</u>** | |
| **<u>Needs/ Problems and additional desirable of family visit</u>** | |
| 23. | Overall did you enjoy your use of the mobile application today? /How did you use the mobile app? ( this question is for experimental group) |
| 24. | In your opinion, what is helped your family from learning today? |
| 25. | Did your family have any kind of problems from your visit today (in term of learning) through exhibition? |
| 26. | On your visit today, is there anything you need from the museum to improve your family experience on museum visit? |
| **27. <u>Additional comment (optional):</u>** | |
| | |

# Appendix 7 Example of Interview Transcripts

**<u>Control Group Family</u>**

Father, age 31 – 40

Son, age 8

14.50 Parent/Father, age 38; Son, age 8.

The family visits the museum every 3 – 6 months and owns the Museum Family Card

Interviewer: what is your family's purpose of the museum visit today?/ What are you expecting from your visit today?

Father: I expected my son to be aware of self-learning in the museum. I, as a father, I accompanied him to give some explanation but did not expect myself to learn anything here.

Son: I wanted to see some new exhibits.

**Part 2 Knowledge about specific contents/ exhibits; Asking and using the personal meaning mapping (PMM) and Family meaning mapping activities (FMM)**

**<u>Question about knowledge and understanding</u>**

**<u>Pre-Visit</u>**

***1. Lucy***

Interviewer: Have you ever heard about the theory of evolution? What do you know about it? What do you know about 'Lucy'? What is your opinion about 'Lucy' and the theory of evolution?

Father: I remember it was a model that looks like a monkey. I was not very interested in the exhibit nor reading the description. I had no idea what the Museum wanted to convey.

Son: I remember it was a kind of black monkey.

***2. The Whisper Dishes***

Interviewer: Can you explain the reflection of sound? / What do you know about 'the parabolic dishes' in the gallery?

Father: It was a model of two dishes placed separately from each other, to which you spoke and listen. The sound would reflect from one dish to the other.

This model uses the parabolic dishes to explain how the amplifier worked. It showed that a sound could be amplified by using the parabolic browser with both dishes. When we whispered to one dish, the voice would be heard at the other dish.

Son: Now I remember I played with it (not drawing any picture). There were two parabolic or curved dishes, between which you speak to. There must be two players, facing the dishes. It explains how the satellite works.

***3. The Plasma Ball***

Interviewer: What do you know about 'Plasma' or 'a Plasma ball' and what is your opinion about it?

Father: I remember this model because I have played with it. It tried to show the four states of matter, which are solid, liquid, gas and plasma. I knew this before visiting the museum.

Son: I visited the Museum many times. I remember most of the exhibits. I have also played with the Plasma Ball. As I remember, it was a spark like when you plug in something, like the flash of lightning. I think it is caused by electrons. I know there are four states of matter but don't know which state the plasma is.

***4. Camera in the Show Case***

Interviewer: Do you know how the camera was invented and/or how it works? Can you tell me?

Father: I remember there was a camera in a glass case but I didn't stop to look at it.

Son: I saw it but didn't stop to take a look.

(Leave the family to see the exhibit before doing the post-visit interview.)

**Post-visit Interview**

***1. Lucy***

Interviewer: Have you ever heard about the theory of evolution? What do you know about it? What do you know about 'Lucy'? What is your opinion about 'Lucy' and the theory of evolution?

Father: It was a model that looked like a monkey rolling their eyes. I didn't really look at it. It was crowded so we moved on the upper floor.

Son: It was a monkey rolling their eyes.

***2. The Whisper Dishes***

Interviewer: Have you seen and played with the giant dishes in parabolic shape on the third floor? What did you learn from it about the reflection of sound?

Father: I played with it today. I remember the exhibit and the reflection of sound. (He explained it to his son.)

Son: There were two parabolic or curved dishes. There must be two players facing the dishes and speaking between them. That is how the satellite works. (He drew the Whisper Dishes, which will be shown at the end of this transcript.)

***3. The Plasma Ball***

Interviewer: What do you know about 'Plasma' or 'a Plasma ball' and what is your opinion about it?

Father: I have played with it and understood its message. It tried to explain the four states of matter.

Son: I remember it and play with it every time I visit the Museum. It was a glass ball with gas and electricity inside. The light could move into our hands.

***4. Camera in the Show Case***

Interviewer: Do you know how the camera was invented and/or how it works? Can you tell me?

Father: I remember there was a camera in a glass case but I didn't stop to look at it.

Son: I didn't stop to take a look.

(Leave the family to see the exhibit before doing the post-visit interview.)

**Part 3 Questions about GLos**

***Questions to explore Skill***

Interviewer: Did you learn a new skill or have done something that you never done before today?

Father: To saw we saw the new exhibition about robots. It was the Matching DNA exhibit that my son enjoyed playing with. There was something about surgery and building the arched bridge. New things that I learnt today are about motion, momentum and hydronic machine, which would be the topics I could expand and teach (him) further. I have visited the Museum for many times and seen many exhibitions. Every time I usually focussed on special activities such as Science Lab, temporary exhibitions, shows and other special events. As for the permanent exhibits, I revisit them every six months. Other new things we did are discussing with each other, exchanging ideas and solving problems together. That helps improve speaking, listening and explaining skills within the family, interactions with each other as well as making some observation on the models and experiment with them.

Son: I did activities with my family, saw new shows and saw the stars.

***Questions about attitudes and values***

Interviewer: Did the museum visit today change the way you think or feel about a scientific concept or process, or how you view it, if yes how?

Father: Our family normally discusses about science. In fact, I would come up with a development plan such as when my son should learn such and such. The reason for visiting here was is to use it as a tool to help recall what he has learnt or what we have talked about and to make the abstract ideas concrete. Also, we can get new topics for further discussions such as how things we see here can be linked to our everyday life.

Son: Here, science is fun. We can really experiment and observe the reactions.

Interviewer: Has your visit changed the way you think or feel about the science museum? If yes, in what ways? (Attitudes toward the museum)

Father: I think it is a good place for parents to bring their children to learn about science and to spend time together.

Son: I quite like the Museum. There are many things to play with and new activities to do. That makes science more fun than in classrooms.

Interviewer: How did you feel about the overall of the museum visit today?

Father: Very good, as always. Very helpful, what we can take from here. In fact, we came to refresh our memories so that he (my son) would not forget what he had learnt.

Son: It was fun. We did an experiment in the Lab, saw exhibits and got new stories to share with friends.

***<u>Question that relate to Action, Behaviour, and Progression</u>***

Interviewer: What did you do in the gallery?

Father: At the exhibition, I usually give explanations and my son usually plays with the models and observe the reactions. I try to develop the habit of observation in him, connect new things he learns with what he has known before and found in every life. My son usually plays with each exhibit and leads me to the ones he is interested. Sometimes he listen but sometimes doesn’t. We then talk further when we get home.

Interviewer: What, if anything, do you think the young people in your group might want to do as a result of today's visit?

Father: I think there may questions that we can discuss more about like every other visit.

Son: I will tell my friends new things I have discovered.

***<u>Question for Needs/ Problems and additional desirable of family visit</u>***

Interviewer: In your opinion, what is helped your family from learning today?

Father: I think it is the conversation among the family, exploring and playing with the exhibit together. In some activities, the staff provided more information.

Son: Playing and experimenting. If I have a question, Dad will explain it or just ask a staff.

Interviewer: Did your family have any kind of problems from your visit today (in term of learning) through exhibition?

Father: Based on my regular visits, I think one problem is how the information is provided at the exhibit. I want the Museum to improve the guide to playing with the exhibit. In Japan or Singapore, they explain theory-based information in one section and the experimenting instruction in another. The third section is the conclusion. Here, the explanation is too simple and not very informative. We can only interact (with the exhibit) without knowing the result outcome such as what it is trying to tell us. Some models do not show the results so we're not sure if they're broken or we didn't play with it correctly.

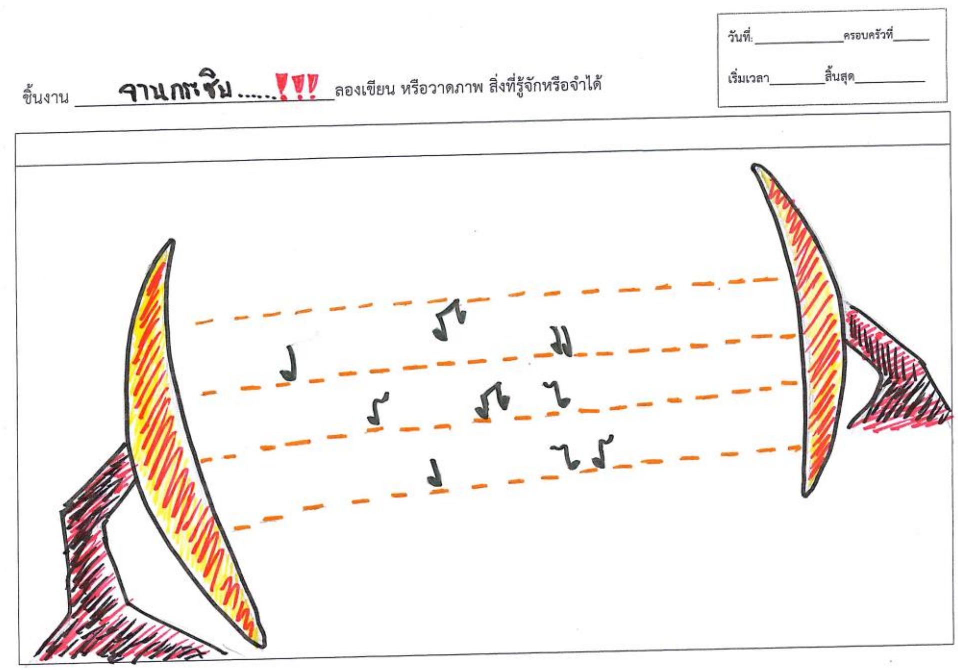
Interviewer: On your visit today, is there anything you need from the museum to improve your family experience on museum visit?

Father: Overall, it's done a good job. There are very few broken exhibits but I want it to improve and keep offering new activities.

Son: I want it to have more exhibits.

***Interview with Family 1 finished 22.40 minutes after the visit.***

## Appendix 8 Example of pictures from children drawing activity

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