Exploring Family Flow Learning: A study of Experience and Learning Outcomes in a Science Museum Makerspace, Thailand

A thesis submitted for the degree of Doctor of Philosophy

By

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ABSTRACT

Visiting informal scientific learning environments, such as science museums and science centres, holds the potential to influence various aspects of visitor's experiences and outcomes. The dimensions encompassed within this framework comprise cognition, affect, attitude, interest, motivation, and behaviour, all of which hold significance in the context of science and the process of acquiring knowledge. The Maker movement represents a notable and influential trend that exerts a deep and far-reaching influence on the process of digital transformation within educational systems and practises on a global scale. This study investigated the experiences of families (herein referred to as family visitors) who participated in the NSM Enjoy Makerspace activity at the National Science Museum of Thailand. The objectives of this study were (a) to observe family visitors learning through NSM Enjoy Makerspace activities at the National Science Museum, Thailand, (b) to describe the factors that encourage family visitors to learn as a maker through NSM Enjoy Makerspace, (c) to study family visitors learning outcomes through NSM Enjoy Makerspace, and (d) to explore family visitors motivation, knowledge, skills, inspiration, and creativity from NSM Enjoy Makerspace via the focus on family learning, experiential learning, flow and immersion and STEM learning. Personally, I believe that the makerspace movement emphasizes creating, designing, and building through various technologies that use, for example, electronics and digial fabrications. This involves using technologies such as 3D printers, accessibility technologies such as iPad, as well as using democratic innovatiton and production processes. The finding of this research will help to identify elements, including maker spaces that support and encourage family visitors to learn across activities. The insights gleaned from this research may be used by museum employees, curators, education teams, and outside educators to promote STEM and family learning. The research used a multi-methods approach to study the experiences and learning outcomes of family visitors to the NSM Enjoy Makerspace, which incorporates questionnaires, site observations, and interviews with visitors. The main activity for observation was a Syringe Rocket activity, in which participants constructed rockets from plastic syringes. Data was collected from families using questionnaires, observations, and semi-structured interviews. Findings illustrated that the makerspace was viewed as a positive learning activity, promoting creative learning and interaction between family members and between children in different families. Results illustrated positive perceptions of the learning activity and learning engagement. The conclusion of the research is that the NSM Enjoy Makerspace makes a positive contribution to family learning through the development of collaborative flow in family learning situations. The study offers several recommendations for the design of museum makerspaces based on the findings. There are also some limitations, including limitations on the age groups and families included and focus on a single activity. The study makes a positive contribution to understanding experiential learning in makerspaces by illustrating how family learning and cooperative group learning occur within the space and ultimately promote interest in STEM activities.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter outlines the purpose behind this research study. It briefly explains how I became interested in museum visitors learning as makers through hands-on activities within a maker space gallery. As part of the research, I will identify and discuss factors that encourage all–age family visitors learning as makers through activities at the NSM Enjoy Makerspace at the National Science Museum, Thailand. I will also explore family visitors motivation, knowledge, skills, inspiration, and creativity as influences in learning as makers through the NSM Enjoy Makerspace zone at the National Science Museum (NSM), Thailand. The importance of family learning in the acquisition and development of knowledge in both children and adults will be briefly outlined. This research could help us understand how families learn together, facilitating stronger bonds and shared knowledge creation. This chapter also briefly describes the background to the Maker Movement more broadly and to the museum-based Makerspace at the NSM in Thailand, along with the development of 'Twenty-first-century learning skills'. The aim and objectives of the study, together with the rationale and significance of the research, will be outlined. The chapter will end with the specific research questions that the study seeks to answer being elucidated, and then I will present the framework of the study (Figure 1).

1.2 Background

This research investigates the phenomenon of the makerspace and what it means for family learning in the context of museums. The wonder of the maker movement is widespread. However, its exact definition is often unclear, and people often do not self-identify as "makers" or associate themselves with an overarching movement (Marotta, 2021). This makes arriving at a clear definition of what a maker is more difficult than understanding the activities that it is associated with. The 'maker' identity is focused on characteristics like creativity, autonomy, and innovation (Marotta, 2021). Being a "maker" also can be said to involve learning to use tools and materials in different and imaginative ways to create something that is not mass-produced but which fulfils a specific need –

functional, aesthetic, or both (Clapp, 2017). For this research, a maker is considered someone autonomous and self-directed in their exploration of tools, materials, and techniques for the creation of any kind, whether or not they self-identify as a maker or with the maker movement.

The National Science Museum, Thailand (NSM) is a state enterprise under Thailand's Ministry of Higher Education, Science, Research, and Innovation (National Strategy Secretariat Office, 2018). In line with the National Strategy of Thailand, NSM follows the government's policy of undertaking research and design and promoting creativity and innovation, accommodating and educating approximately 600,000 visitors annually, with the majority being school children or children visiting with their families (National Science Museum, 2018). One of the main functions of the science museum is to teach children about science and technology in an age-appropriate and engaging way (Achiam and Sølberg, 2017). The government's policy and the mission of the NSM are to promote STEM (Science, Technology, Engineering, and Mathematics) Education and to educate people in these disciplines to promote the sustainable development of the country (National Strategy Secretariat Office, 2018; NSM, 2018).

The NSM Enjoy Makerspace at the National Science Museum is a place where visitors can:

1. Understand the word "maker" and value what they have created.
2. Develop skills, imagination, and creativity.
3. Be provided with the facilities and resources, such as tools, materials, etc., to engage in activities and gain enjoyment and inspiration.

The theme within the maker space emphasises the idea that, for all ages of people, "everyone can be a make", encouraging people to be innovative and creative. This research will study learning in a maker space amongst different age groups because visitors to a science museum are of all ages, such as children, teenagers, adults, and elders. The Open Education Database (OEDB, 2018) has noted that the United States of America has more than 135 million adult makers, which is more than half of the total adult population in the USA. These makers are identified as learners who learn by "doing", which could encompass a wide group of demographics, from age, gender, and socio-economic status to others. To this end, The White House even held an inaugural Maker Fair in 2004, inspiring then-President Obama to declare an official National Week of Making the following year. This led to a surge of international interest and has sparked research into learning more about maker spaces and how these might benefit the communities in which they are located.

The NSM Makerspace provides activities such as making a syringe rocket, offering participants an opportunity to learn through making and creating such an object. The materials and tools necessary are provided to participants of the activity. In addition, an assistant will guide the participant in using the relevant tools and machines, while an educator will explain the science behind the process. The possible range of activities (within a Makerspace) might include:

1) Cardboard Construction
2) Prototyping,
3) Woodworking,
4) Electronics,
5) Robotics,
6) Digital fabrication and
7) Building kinetic machines and textiles and sewing (Copper, 2013).

My experience working as an educational programmer (at the NSM) has led me to study all ages of visitor learning through the NSM Enjoy Makerspace at the NSM, Thailand. The research described here builds on the theme that "everyone can be makers" through the NSM Enjoy Makerspace activities at the NSM. The NSM Enjoy Makerspace provision encourages knowledge, understanding, and maker skills in children, teenagers, adults and elders. One of the unique aspects of the NSM Enjoy Makerspace is that it is oriented toward family learning, encouraging participation in learning activities by all members of the family. This aspect of the Enjoy Makerspace sets it apart from many other youth-oriented maker spaces, which are often based in schools and libraries and focus on independent learning (Keune and Peppler, 2018). While this may be somewhat unique, a recent and extensive review of the maker space literature did not identify any other studies which were situated in a family-oriented learning space like the Enjoy Makerspace (Mersand, 2021). Therefore, the main aim of this research is to investigate how the NSM Enjoy Makerspace activities encourage participants' learning. The primary concern is the features of the NSM Enjoy Makerspace setting, such as the environment, facilities, and resources available for education, which are well-established factors that encourage learning (Fleming, 2015). Another aspect of the research is looking at how age and gender influence learning engagement in the maker space. This aspect of the research is based on studies that indicate female learners experience maker spaces differently compared to male learners (Tomko et al., 2018) and the pedagogical principle that learners of different ages require different learning structures, content, scaffolding, and other supports for learning (Coiro, Dobler and Pelekis, 2019). The third factor that encourages participants' knowledge from the NSM Enjoy Makerspace activities considered is the development of individual learning dispositions, which are influenced by engagement in makerspace activities (Tan et al., 2022). As Tan et al. (2022) have explained, the development of 21st century learning dispositions is crucial for overcoming inequity in schools. Therefore, finding ways to encourage children to develop learning dispositions that emphasise creativity and independent thought is a priority for the NSM Enjoy Makerspace. Yet, despite the presence of research design that emphasises the learning dispositions, it can be noted that there needs to be more research surrounding experiential learning connected with STEM subjects, including Science, Technology, Engineering, and Mathematics. Although existing studies have emphasised developing curricula such as STEM and their effectiveness on the learning and development of children, specific research that explores the inter-relationship between makerspace activities, STEM learning, and experiential learning together is limited. In this research, many facets of STEM learning will be examined in relation to NSM Enjoy Makerspace activities. These activities are anticipated to facilitate the growth of STEM skills, nurture a sense of appreciation for science, boost knowledge and comprehension, promote good attitudes and values regarding STEM education, and encourage pleasure, inspiration, and creativity. Furthermore, the research will examine the extent of involvement in makerspace operations, patterns of learning behaviour, and overall academic advancement. The intention is that this research will benefit the National Science Museum's education programs, visitors learning and other science museums more widely.

1.3 The Maker Movement

Anderson (2012) indicated that the advent of the maker movement, a modern phenomenon where designated spaces are utilised for creating and innovating, has garnered interest from a diverse array of individuals across multiple fields. Certain academicians, such as Dorph and Cannady (2014) and Hatch (2014), posit that this nascent movement holds the potential to influence a multitude of sectors, encompassing manufacturing, the economy, and science and technology. Advocates of this trend perceive the maker movement as a means to democratise education and endow learners with the aptitudes and knowledge to shape the world they inhabit, as also addressed by The White House (2014). Authors such as Dougherty et al. (2013) explicitly outline the ambitions of the maker movement to revolutionise practical scientific education in Thailand through the integration of "experimental plan" to encourage creativity and autonomous learning mind-sets. While this is an ambitious claim that overlooks problems with the maker movement, such as lack of solidarity and consistency in definitions or objectives (Marotta, 2022), it is still worth investigating to what extent the maker paradigm can affect education, which is the intention of this research.

Much early support for the maker movement as an educational paradigm came from the United States, including financial support of pilot makerspaces in museums by the National Science Foundation (NSF) (2014) and political advocacy for the maker movement by President Obama (White House, 2014). This geographic focus is also found in the academic literature, with almost half of the 150 studies reviewed by Mersand (2021) taking place in the United States. Increasingly, however, there has been interest in the maker movement as an educational paradigm within Asian contexts. Tan et al. (2022) pointed to makerspaces as a tool for experimental STEM learning. This could help close significant skill gaps and promote the overall development of what the authors term

"21st Century Skills", including science and technology literacy skills. Furthermore, the value of informal learning in maker spaces and similar learning spaces is becoming more recognised (Tan et al., 2021). Therefore, investigating the NSM Enjoy Makerspace offers more opportunities to understand how the maker movement is developing as an educational movement in Asia, building on studies like those conducted by Tan et al. (2021, 2022) in Singapore.

The Institute of Museums and Library Services (IMLS, 2015) suggested that adopting a more comprehensive stance seeks to foster all "21st Century Skills" via the maker movement, encompassing critical thinking, problem-solving, creativity and innovation, communication and collaboration, and a series of literacies. Former IMLS Director Susan Hildreth (2012) viewed the movement as a grassroots initiative that ignites passion and opens up new occupational opportunities. Nonetheless, a number of academics, like Vossoughi and Bevan (2014), have stressed that more clarity on the underlying motives and objectives of national interests within the maker movement is urgently needed. This issue continues to be a recurring theme in academic writing, as Marotta (2021) draws attention to the maker movement's lack of a clear conceptual framework and underscores the need for a more defined sense of purpose or direction. Furthermore, it is noteworthy that a significant amount of research has been conducted in relation to the maker movement. But it is crucial to recognise that since this body of work has covered such a broad range of various makerspace models, it has been marked by its fragmented nature (Mersand, 2021). This remark implies that a more in-depth analysis of the makerspace as a favourable learning environment is urgently needed and, in the literature, will be briefly discussed. This is one of the main reasons that motivated us to start this study project. This issue is investigated in more detail in the literature review, as it is a key issue.

1.4 The Universal Design of the Maker Space

The emphasis at NSM Thailand is on an awareness of the importance of science and on stimulating inspiration and innovation in creating new things as part of the foundation of a developing country (NSM, 2004). The NSM Thailand also focuses on providing accessible science-based interactions for people of all ages and in as many ways as possible to promote awareness and enjoyment. Its ultimate goal is to build a group of citizens who appreciate science, their position in life, and the nation's growth (NSM, 2004).

In general, museum-based maker spaces tend to foster a "… tinkering approach to problem-solving …" (Oats, 2015, p.11) in visitors, helping spark more curiosity in new audiences in maker space activities. These spaces commonly reflect the concept of hands-on creation that underlies the broad maker movement, which leads to visitors becoming curious about scientific issues. Like other makerspaces, private donations have provided the NSM with funding for its maker space activities in recent years (Mattioli, 2021). This has meant that museums like the NSM could make expensive high-tech devices such as 3D printers readily accessible to visitors. The size of the makerspace will define the types of programs, as well as the full curriculum for makerspace activities.

The Universal Design (Burgstahler, 2020) of the maker space encourages the concept of designing spaces and goods to be accessible to as many people as possible. The design adapts to a broad range of individual preferences and skills. For example, a museum allows a visitor to choose to read or listen to a description of the contents of a display case board. The idea of universal design came from disability access, which involves making facilities and equipment more accessible to disabled persons (such as wheelchair users, those with sight issues, and deaf and hard of hearing people) that are accessible by everyone irrespective of their (dis) ability, age, educational level, etc. The NSM Enjoy Makerspace encourages making artefacts and products (and other activities) by users of various abilities, ages, learning methods, languages, cultures, etc.

The objectives of the National Science Museum, Thailand, can be briefly characterised as experiential learning of science and technology. Experiential learning is a learning approach in which museum visitors are encouraged to engage not just at an intellectual level but at a sensory and experiential level with the museum's content (Henderson and Atencio, 2007). Younger children, in particular, learn through social and physical interaction within the environment (Henderson and Atencio, 2007). Therefore, experiential learning, or learning by doing, is one of the museum's main approaches to reaching younger visitors. Experiential learning is also particularly helpful for certain disciplines often taught in museum contexts, ranging from the creative arts (Piscitelli and Penfold, 2015) to STEM (Lykke et al., 2021).

Experiential STEM and technology learning, particularly, has been the focus of development in science museums, including new technologies such as virtual reality (VR) and tools such as maker spaces that allow individuals to engage in technology-related activities (Lykke et al., 2021). While the National Science Museum, Thailand combines approaches, including classical styles of the didactic exhibition and experiential learning, the main focus of newer exhibits is on experiential learning. It is in this learning domain that the current research is situated.

1.5 The 21st Century Learning Skills

A key concept in maker-space education is the development of 21st Century skills. These skills include a wide spectrum of aptitudes taught at all levels of education to prepare students for life beyond secondary school and help them integrate easily into a constantly changing and dynamic job market (Tan et al., 2021, 2022). The term "21st Century skills" refers to a broad set of knowledge, skills, work habits, and character traits, according to the Glossary of Education Reform (2016). These skills are not easy to define, have not officially been categorised, and "… several related terms including applied skills, cross-curricular skills, cross-disciplinary skills, interdisciplinary skills, transferable skills, transversal skills, noncognitive skills, and soft skills, among others …" have also been used to describe the knowledge and skills, "… commonly associated with 21st century skills" (Glossary of Education Reform, 2016, p.1). These skills entail a range of capabilities that children need to develop for success in the "information age" (Thoughtful Learning newsletter, 2020).

According to Trilling and Fadel (2009), "21st century skills reflect the idea that the world has changed so fundamentally in the last few decades that the roles of learning and education in day-to-day living have also changed forever" (p.3). Students develop, and the skills they learn (21st Century skills) can be applied to new situations and experiences to gain new competencies, assist in building relationships, and lead the students to assume new roles. Stauffer (2020) suggested that 21st Century skills comprise 12 abilities that students need to succeed in their careers. The Partnership for 21st Century Skills (2015) separates knowledge, skills, work habits, and character traits into three categories and 12 subcategories, as shown in Table 1 below. One question of this research is how makerspaces such as the NSM Enjoy Makerspace can contribute to the development of 21st Century Skills among the children whose main audience is, and potentially among other audiences, such as parents. Tan et al. (2022) noted that the establishment of makerspaces in contexts like schools and libraries was intended to address the need for 21st Century Skills development. Even so, they questioned whether these makerspaces could be effective, given that learning within them was still controlled and structured in the school context. For example, learners could only access them at certain times or were restricted to certain activities (Tan et al., 2022). Research among university students has shown that makerspaces can promote some 21st Century Skills, but more is needed on their own to foster learning in areas like leadership and entrepreneurship (Rayna and Striukova, 2021).

The evolving education system in the 21st Century Skills has greatly impacted scientific education in Thailand. Makerspaces are now common in museums and greatly impact people's educational experiences, regardless of the age of the learners, these may be students, their parents, or other guardians. These dynamic situations help develop critical learning abilities for the needs of the twenty-first century. Makerspaces enhance critical thinking and problem-solving skills. Science museum exhibits enhance students critical and creative thinking skills, enabling them to solve real-world problems. This exercise helps improve critical thinking and enhances understanding of scientific concepts. Collaboration is important here. Makerspaces support collaboration and group projects by promoting effective communication and fostering a creative atmosphere. Interpersonal skills are crucial in today's world. Children develop these abilities through cooperation in creating, building, and exploring. Science museums can use their makerspaces to promote digital literacy.

Thanks to technology being integrated into the scientific field, students can now use advanced tools and software to improve their digital technology skills. Makerspaces in Thai science museums help develop resilience and flexibility. Using iterative design techniques and experimenting helps individuals learn to embrace failure as an essential aspect of achieving their goals. Developing this mind-set is important in a time of fast technological advancements. Makerspaces at science museums are important for Thai students of all ages. They help develop critical skills necessary for success in a constantly changing world. These areas enhance students' education by developing critical thinking, collaboration, technical skills, and flexibility.

1. Learning Skills	2. Literacy Skills	3. Career and Life Skills
1.1 Knowledge and skills 1.2 Problem Solving 1.3 Communication 1.4 Collaboration 1.5 Creativity Skills	2.1 Information Literacy 2.2 Technology Literacy	3.1 Flexibility and Adaptability 3.2 Self-Direction 3.3 Social Skills 3.4 Productivity 3.5 Leadership

Table 1: The 21st Century Skills
(Source: Partnership for 21st Century Skills, 2015)

1.6 Experiential Learning

Experimental learning in makerspaces involves hands-on experiences where learners explore, create, and experiment with various tools and materials (Mersand, 2021). The technique focuses on experiential learning, where individuals learn by actively trying things out and making mistakes. As stated by Richterich (2022), this method helps develop problem-solving skills, encourages creativity, and improves understanding of ideas. Therefore, it is seen as an effective method for skill development and gaining knowledge. Experiential learning is investigated here as the main mechanism of learning within the NSM Enjoy Makerspace. Experiential learning is "the process of creating knowledge through the transformation of experience" (Lai et al., 2007, p. 326). In other words, it is a process by which individuals learn through interaction with the social, physical, and information environment. Furthermore, experiential learning is not just a cognitive process but entails affective (emotional) involvement with the learning environment, physical interaction, and other modes of learning (Kolb et al., 2014). Thus, experiential learning adds up to more than common repetitive learning.

Experiential learning, which requires learners to read about and assimilate book-based knowledge on a topic and try it out, is well-established as an approach for STEM learning for university and postgraduate students, Makerspaces demonstrate how learning may be done experimentally. The example-s provided demonstrate how makerspaces and computer sciences are often related. They do not, however, solely apply to technologists and businesses with a technological focus. Applying the fundamentals of active, self-directed, project-based learning to various cultural organisations missions and subject areas may be a successful strategy for involving learners. Organisations have an opportunity to improve creative teaching techniques via the maker movement, which provides an alternative to the assessment-driven educational system (Dawson et al., 2011). Experiential learning is often framed as project-based learning, where students undertake a real-world problem-solving exercise (Franse et al., 2020). For younger learners, learning by doing can be highly effective for learning technology skills (Brown et al., 2006). More youthful learners can benefit from simply having access to instructions for different technologies, which they can use in various ways to achieve creative and technologically interesting outcomes (Brown et al., 2006). Experiential learning in the context of makerspaces does typically teach learners about how to use the technologies themselves, but far more importantly, their use ingrains technology use, exploration, and creative experimentation as habits which are then applied in many other contexts (Richterich, 2022). This study explores how experiential learning is used in Makerspaces to offer visitors more than just looking at displays. Instead, they can engage in technology activities to enhance their learning experience. A recent review of the literature on maker spaces has identified a few studies that have investigated the social context of maker space learning, particularly social scaffolding (learners helping each other) (Mersand, 2021). However, while emotional and physical impacts are suggested within the makerspace literature, Mersand (2021) identified few studies that investigated these phenomena. This research investigates the specific social and emotional context of family learning as a tool to fill this gap.

1.7 Technology & Learning Experience

The integration of technology within the educational domains tends to have a significant role in enhancing the overall learning experience of students (Christensen, 2002). In the School of Education (2020) article, the authors have cited that, conventional educational practices, such as rote-learning, or even in-class physical attendance have led to significant challenges for the students, and these have not improved over the years. In light of these challenges, the study on education and pedagogical research presented by Selinger (2009) and Dexter et al., (1999) acknowledges technology as a catalyst, that drives experiential learning for the learners, and provides them with opportunities to engage actively with tools and materials – enhancing and enriching the learning experience. The enriching experience provided through the integration of technology can be as simple as the use of an iPad for learning, to the complexities of using virtual reality technology for immersive simulation learning. Growing examples of using technology in the modern day is the use of virtual reality (VR) and augmented reality (AR) technology, Harris et al. (2023) states that virtual reality (VR) technology is a pivotal element in improving human skills training, such as in military and medical education. It enables the learners to immerse into gamified learning practices. However, using VR technology can also have a significant impact on a makerspace, specifically in terms of children's learning. A study by Maryville University (2024) reported that the evolution of children's use of technology has contributed to independent learning practice, in a much quicker and efficient manner than usual. Recognizing the growing role of technology, the national science museums Thailand, including the NSM Enjoy Makerspace, employs the use of technological products such as iPads that create a significant impact on learning intention and behaviour. This also provides and promotes digital literacy among the students, providing and improving their digital technology skills, allowing learners of all age to develop critical skills in the future.

1.8 Gender & Learning Experience

In existing research, makerspaces are recognized as a gender-neutral space for learning (Lawrence, 2024; Eckhardt et al., 2021). These authors have stated that makerspaces practice learning that can provide individuals with hands-on experience whereby tasks challenge gender stereotypes and provide an inclusive learning atmosphere for the students. In addition to that, authors such as Seo and Richard (2021) and Steele et al., (2018) stated that a makerspace is a universal design that focuses in providing accessible and welcoming new learning practice. Furthermore, the findings presented by Seo et al., (2021) reported that, the universal design (UD) of the makerspace is based on several digital and conventional frameworks, including web accessibility, simplicity, collaboration, flexibility, likability, and diversity. In addition, makerspace practice involves practice learners of all ages and genders, providing a multi-sided, accessible, and easily understood environment. Furthermore, the success of the NSM Enjoy Makerspace as a family learning venue depends on its ability to foster an inclusive atmosphere that encourages learners of all genders to explore and engage with STEM activities collaboratively (Linda Hall Library, 2024; National Inventors Hall of Fame, 2024). In the context of this study, the researcher will acknowledge the role of gender in defining the key attributes of the children (subjects of the study) in exploring the change in their behaviour.

1.9 Family Learning

Given that the design of the NSM Enjoy Maker Space aspires to be inclusive of all, it encourages a wide range of families to attend. Families are one of the main visitor groups at the NSM Enjoy Maker Space – often consisting of younger and older children and teenagers, parents, grandparents, and other adult guardians. According to Borun et al. (1997), many makerspaces are designed for family learning, in which children explore the science and technology exhibited within the social environment and with the support of their family group. In the context of museums, exhibits designed to facilitate family learning should be "multi-sided… multi-user… accessible… multi-outcome… multi-modal… easily understood… and relevant… to visitors existing knowledge and experience" (Borun et al., 1997, p. 280).

The extent to which the Enjoy Makerspace can be considered successful as a family learning venue depends on how much it allows for the learning process to occur through discussion, interaction, and group engagement as highlighted by Feng et al., (2014). Of course, the physical makerspace itself is not responsible for all the learning. Assessment of family learning in museums has shown that parental pre-knowledge significantly influences family learning (Franse et al., 2020). This suggests that for STEM learning to occur in the Enjoy Makerspace, it needs to facilitate family learning, which encourages learners of all ages to explore and engage with STEM.

1.10 Government Policy, SDGs and Cultural Values for Lifelong Learning

In Thailand, the government is very keen on education and life-long learning, and particularly on the field of science and technology. The government of Thailand has strived to make education of its population a priority, offering citizens practical learning opportunities. An example of this is the development of the "NSM Enjoy Makerspace" which enables families to participate in science and technology related interactive and experiential learning activities. The cultural values of Thailand that extol the virtue of continuous learning and lifelong learning (Ratana-Ubol, 2021), are reflected in the educational policies and programs of the government which focus on educating science and technology and providing families with hands-on learning experiences. This is reflected in the numerous family-oriented learning activities being funded by the government like science and technology workshops, maker fairs and STEM festival, mobile science center, and online learning platforms. The Family Action Plan 2020 to 2022 stands as a deep illustration of the Thai government's care for family education and opportunity creation for Thai people.

The Thai government's efforts are alligned with the Sustainable Development Goals (SDGs) by United Nations which target at SGG 4. The primary objectives of this endeavour are to ensure that education is accessible to all, regardless of their background, and to promote lifelong learning opportunities. With the help of hands-on learning activities and nurturing the creative and innovative spirit, these programs are designed to underpin the development of an educated and technological high society.

1.11 Individual Learning Dispositions

Individual learning disposition can be defined as the practices or unique habits, attitudes, and inclination of learning that each individual holds towards learning practices. Herein, there are several contexts that influences the individual learning disposition, with few of the key factors discussed earlier such as, gender and age (Maryville University, 2024; Lawrence, 2024; Eckhardt et al., 2021). In addition to these demographic factors, it can be stated tha there are several factors, that includes elements such as active learning practices, collaborative/cooperative learning practice, and immersive learning practice. The findings of this study showcased that; active learning is important considering the participants are engaged in hands-on experiences considered crucial for developing meaningful experiences. In addition to that, active learning practices work in tandem with collaborative/cooperative learning, which encourages working together, sharing materials, and collaborating on projects to foster posiive learning experiences. Finally, immersive learning involves engaging wih the concept of learning flow. Flow-based learning is a key factor that drives the integration of immersion with the learning process, whereby the learners are intrigued and fascinated with the concept and notion of learning. These learning dispositions can enhance the practices associated with problem-solving and critical thinking, family involvemen and bonding, and motivation and creativity – as discussed later in the findings of this study.

1.12 Aims, objectives, and research questions.

This study aims to investigate the experience of family visitors participating in making activities in the NSM Enjoy Makerspace at the NSM, Thailand. Based on this, the following objectives are addressed:

1. To develop visitors learning through NSM, Enjoy Makerspace activities at the National Science Museum, Thailand.
2. To the factors such as gender and age differences that encourage family visitors to learn as a maker through NSM Enjoy Makerspace.

3. To study visitors learning outcomes through NSM Enjoy Makerspace
4. To explore family visitor's motivation, knowledge, skills, inspiration, and creativity from NSM Enjoy Makerspace by focusing on family learning, experiential learning, flow and immersion and STEM learning.

The following are the research questions:

1. What are the family visitors learning outcomes as a maker through NSM Enjoy Makerspace?
2. How do family visitors learn from the NSM Enjoy Makerspace activity?
3. What knowledge, skills, inspiration, and creativity are derived from NSM Enjoy Makerspace?
4. What factors encourage family visitors to learn with the NSM Enjoy Makerspace activity?

1.13 Rationale and Significance of the Study

This research will study all-age family visitors learning as makers through the NSM Enjoy Makerspace at the NSM, Thailand. While the study does not assume that family visitors are the only users of the Enjoy Makerspace (they are not), the interest of the study lies in the particular social context of family learning. In addition, the aim is to identify and describe factors that encourage all-age family visitor learning within the NSM Enjoy Makerspace activities. This research is significant in that it is the first study to investigate how visitors of different ages learn in the NSM Enjoy Makerspace, Thailand. In addition, the studies contribute to a relatively limited literature on makerspace activities in Asia, as the majority of research has been conducted in the United States and, to a lesser extent, Europe (Mersand, 2021). According to Mersand's (2021) review, there are also few investigations of museum-based makerspaces in Asia, with most taking place in school or library settings which are not explicitly family-focused. In broader theoretical terms, the study aims to contribute to a better understanding of family learning and how cooperative engagement in activities such as those offered at the NSM Enjoy Makerspace can not only contribute to knowledge construction but also deepen family bonds through shared knowledge creation. Therefore, the research contributes to a novel understanding of the

NSM Enjoy Makerspace as an example of makerspace contributions to family learning. This study will benefit museum staff, curators, museum educational teams, and external educators in developing activities for the general public. In addition to these generic benefits, the following are also additional gains the academic community and other stakeholders can derive from undertaking this study:

Improving comprehension in the field of Family Learning	One of the significant aspects of this study is its focus on family learning in a museum context. Family learning involves a dynamic interplay of factors such as parent-child interactions, the influence of age and family roles, and socio-cultural background. This research could help us understand how families learn together, facilitating stronger bonds and shared knowledge creation.
Supporting Maker Culture	The maker culture promotes creativity, problem-solving, collaboration, and self-efficacy, which are all essential 21st century skills. The research could help understand how museums like NSM can support the maker culture and ensure the learning experience's effectiveness.
STEM Education Promotion	STEM fields (Science, Technology, Engineering, and Math) are often seen as the backbone of innovation and societal advancement. This study can identify effective strategies to engage families in STEM education through hands-on, experiential learning.
Museum Education	Expanding the Body of Knowledge in Museum Education: The research can add valuable insights to the broader field of museum education and visitor studies. It can provide a clearer picture of how visitors interact with exhibits, use them to learn, and the factors that encourage active learning in such informal education settings.
Updating Museum Procedure and Practice	The study's findings could directly inform policy and practice in museums. They can use this knowledge to design exhibits and activities that better serve their visitors and meet their educational mission.

Supporting Global Education Goals	This research aligns with the broader global goals of inclusive, lifelong learning. Understanding how to create engaging, educational environments in museums

Table 2: Rational and Significance of the study – the Crux of the benefits of the study

Over the course of this research study, some of the common themes and findings in terms of individual learning disposiitons that were found includes,

1.14 Positionality Statement

During the period when the research was conducted, I was employed at the National Science Museum in a role that involved the development of educational activities throughout the museum. I was tasked with identifying areas of interest to our visitors and developing educational activities that would enable exploration and engage our visitors. This included activities in the Enjoy Makerspace, such as the Syringe Rocket activity that was used as the basis for observation in this study, and also other creative, educational, and exploratory activities throughout the museum.

My particular focus was on activities for our early childhood (ages 2 to 5), primary (ages 6 to 12) and secondary (ages 13 to 18) visitors. While the NSM is intended for all ages, and we aim to both inform and entertain all our visitors, our educational activities are particularly designed for our young visitors to spark their interest in STEM and encourage independent and creative exploration. I took this focus into my research with me, which explains why (as will be shown later) my approach to understanding family learning was "child-first". However, family learning also entails the teaching of older family members, both from the activities and from their children. My research was also influenced by my own les as an educator and student. As a woman interested in the STEM field, I am keenly aware of the challenges that young girls face in translating their interest in STEM into an active career. Therefore, I aim both in my work and in this research to identify how I can make STEM more accessible to girls not just sparking their interest, which is not lacking in my experience – but helping them to see themselves as scientists and engineers. This personal ethical position was part of the motivation for this research.

Finally, although this research is critical of the concept of the maker space, as a researcher, the researcher believes that maker spaces are an important space for independent, creative, experiential learning for children and young adults. I view creative learning through unguided (though scaffolded) experimentation as a crucial part of learning to become a scientist and develop an open and experiential approach to knowledge. Therefore, while the NSM Enjoy Makerspace is not perfect – which can be said for all makerspaces – I undertook this research with the view that it is fundamentally a place not just to learn science facts but how to learn through imaginative play and discovery.

1.15 Key Terms

This research employs several key terms, including (a) family learning, (b) experiential learning, (c) immersion, and (d) flow. The definitions of the concepts discussed in this literature are presented as follows.

- **Family Learning:** The concept of "family learning" is the process of engaging learners within a family, focusing on generational learning as siblings (Feng et al., 2014). The idea of family learning combines a group of family members, irrespective of their demographic factors, to pro-create practical learning experiences. A research article by family learning expert Lynn Dierking (2022) stated that museums and libraries are natural settings for establishing a family learning experience. According to Dierking (2022), museums play an important role in developing a community by providing a place where people can explore and learn. Furthermore, research papers like Falk and Dierking (1998) indicate that families use museums and other communal institutions (for instance, zoos, aquariums, and botanical gardens) to develop their and their children's interests and establish an environment of free-choice learning. An interesting oversight in the literature is that within-generation learning (e.g., learning that takes place through interactions with siblings or cousins) is often overlooked, even though it is important. This research uses a broader notion of family learning that includes both inter-generational and within-generation learning to address this gap.

- **Experiential Learning:** Experiential learning (ExL) is defined as the process of learning through experience (Kolb, 2000). More simply, the model of experiential learning states that the more an individual "does" something, the more likely they are to learn (or some studies indicate a quicker learning approach). Experiential learning has been described as the process of effectively solving problems, improving performances, and improving the learning and development process (Experiential Learning Institute, 2022). Reflective assessment and papers have further stated that the experiential learning process combined with reflecting on the experience is expected to enhance the learning and development process. In a family setting, learning in museum-based environments, as stated by Falk and Dierking (1998), is expected to create a positive learning experience.

In addition to the learning-based concept, two of the key factors that are required to be defined in the context of this study include the concept of "flow" and "immersion". These concepts relate to the experience of learning, which, as discussed above, is one of the main issues explored here. To a certain extent, the concept of flow and immersion has been addressed in the study by Michailidis et al. (2018). A brief review of the definition of the concepts is presented as follows, while both (to a certain degree) are associated with each other.

- **Immersion:** Immersion is a psychological state wherein an individual has undivided attention (complete absorption) in a specific task or activity (Michailidis et al., 2018). There are several means of creating an "immersive experience". For instance, in the article by Arm (2022), the concept of "immersion" was defined as transporting audiences (players in a gaming context, audiences in a video-based context, or learners in learning and development), which would allow creating a strong flow.
- **Flow:** Flow, a concept coined by psychologist Mihaly Csikszentmihalyi in the 1970s, denotes the state of complete immersion in an activity. The idea of flow, according to psychologists, is the statement of total immersion in an action

(Nakamura and Csikszentmihalyi et al., 2014). A higher degree of flow is expected to create a sense of excitement and success (achievement), increasing the motivation for learning. According to Linkinen (2019), flow requires a balance between skills and challenge of learning, the presence of both action and awareness during the learning process (experiential learning), clear goals and ability to acquire engaging feedback, loss of self-reflection and a sense of time, and finally, a strong degree of concentration. Combined, these are expected to create a strong flow.

1.16 Overview of the Study

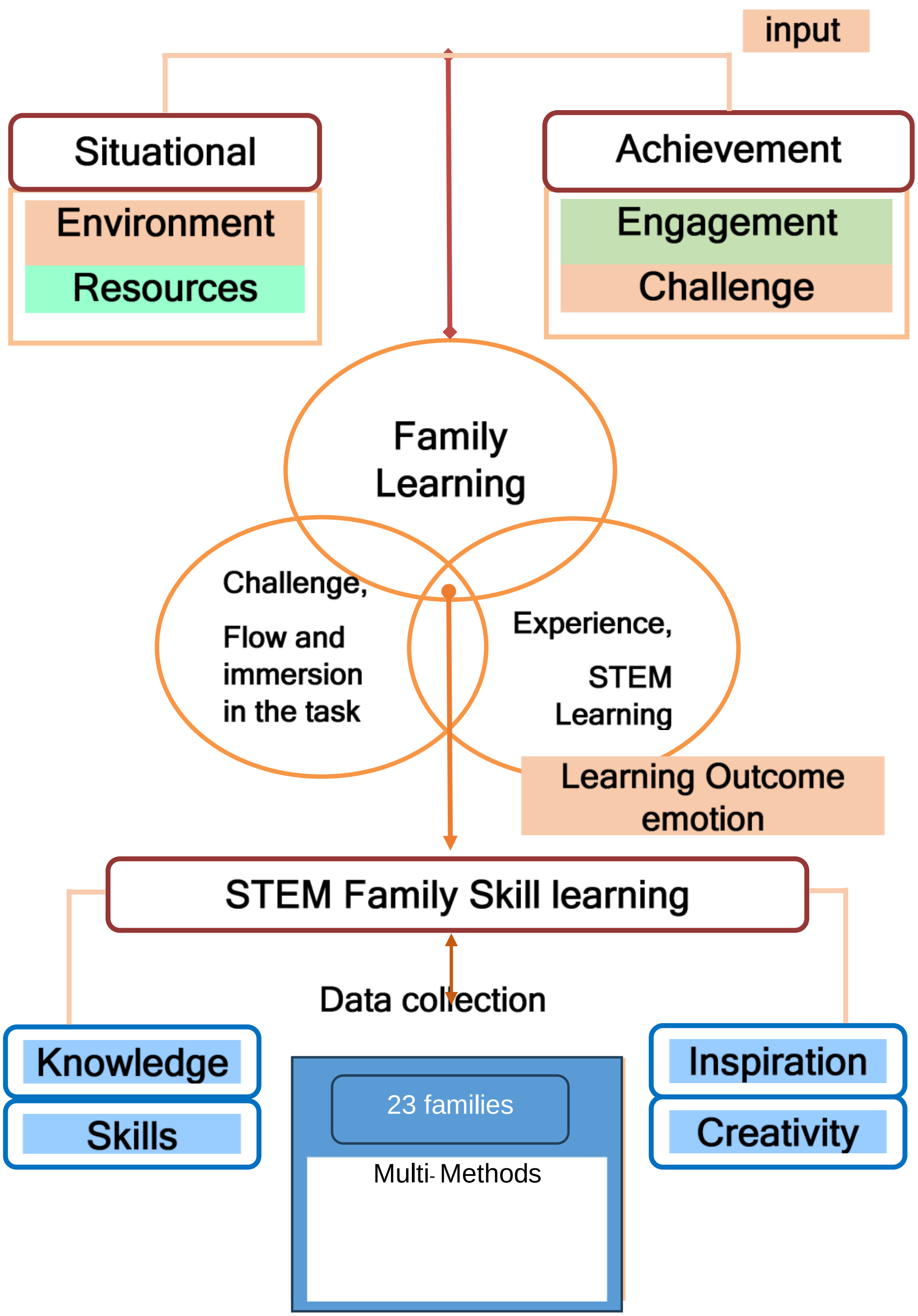

Figure 1: Overview of the study

1.17 Roadmap of The Study

Chapter 1: Introduction

This first chapter, the Introduction, provides an overview of the study's background, aims and objectives, and significance. The chapter outlines the maker movement' importance and the maker space's universal design in promoting 21st century learning skills and experiential learning. The chapter also discusses the role of government policy, cultural values, and SDGs in fostering lifelong learning and provides definitions for key terms used in the study.

Chapter 2: Literature Review

In the literature review, the researcher aims to provide a detailed discussion of various concepts, theories, and models concerning the topic under discussion. This revolves around areas such as institutional agents and policy development in the context of Thailand, including a meeting of the Thai education system, culture, and family learning. Next, the primary entity is discussed, which is NSM, from its core perspective. The narrative extends to a detailed exploration of the NSM's "Enjoy Makerspace" initiative, which investigates various facets of the learning space such as universal design, focus on STEM skills and learning resources. The chapter then turns to empirical research studies and draws upon foundational theories that underpin the concept of maker spaces. Among these are constructivism theory, which suggests that learners construct knowledge through experiences; Education for Sustainable Development (ESD), which aims to empower learners to make informed decisions for environmental integrity, economic viability, and just society; and finally, a conceptual model that encapsulates the educational potential of maker spaces.

Chapter 3: Research Methodology

The methodology in Chapter 3 presents a detailed description of the process that has been undertaken in the making and completion of this research project, dwelling primarily in the "research onion" model, focusing on areas such as research design, aims, focus, research philosophy and approach, including the research method, time horizon, and study limitations. The chapter also outlines the sampling method, including the population and sample, and provides information on the research method of data collection, including observations, questionnaires, and interviews. A detailed presentation of the various types of methodology implemented is also presented in this chapter, which includes both qualitative and quantitative methods, which points towards a multi/ mixed/ bricolage methodology. The chapter also covers the data collection process, the reliability and validity of the data, ethical considerations, and data analysis. The data analysis, in particular, takes a thematic evaluation, following a bricolage strategy, where themes are formed from each of the primary research instruments, which leads to the formation of conclusive or more or less a broader encompassing theme taking into account how each research instrument contributed to the study and the finding.

Chapter 4: Data Analysis and Findings

The aim of Chapter 4 is to present the data analysis and key findings. The structure of this chapter will be descriptive, with a conclusive discussion included as well. It will begin with the research instruments used and their results in a very descriptive manner, followed by the formation of key themes from each of these research instruments. Next, a discussion is presented based on the key aims and objectives of the study, in which I aimed to cross-check and do a comparative analysis between the novel findings of this study and the past results from the literature review. The reader should note that chapters 2 and 3 were modified after writing chapter 4 to be more critical of the novel findings from the research.

Chapter 5: Conclusion and Recommendations

The final chapter is the conclusion and recommendation. The goal of this chapter is to sum up the main findings of the study and the overall process into a shorter description, addressing both the conclusive nature of the finding, the possible limitations and potential future studies. Moreover, the chapter also engages the reader in evaluating the different context in which the findings can be applicable and how it has relevance to the NSM makerspace. As the researcher (myself) is a member of the NSM, the conclusive chapter is vital in addressing the key issues and how makerspace, although a concept brought in for many years, still needs to be fully comprehended by the general population. Therefore, this chapter addresses this and provides a summary.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to the Chapter

This chapter will outline pertinent literature discovered during the literature review for this research, including Thai government policies such as the National Strategy (2018 – 2037), the Family Action Plan 2020 – 2022, and the National Education Act of 1999 (amended 2002). The letter outlines the Thai education system's various types of education (formal, non-formal, and informal). The term' 21st Century skills will be defined, and the skills therein are briefly outlined. A discussion of experiential learning will then take place and how technology skills can be learned through such a medium. The concept of a "makerspace" will be discussed, and relevant literature will be outlined. The structure and activities of the NSM, Thailand, will be described within this chapter. This study follows the notion that everyone can be makers through the Enjoy Makerspace and seeks to investigate the motivation, interest, achievement, and self-efficacy of visitors to the makerspace activities at the NSM, Thailand. Through informal learning, this research focuses on learning from all ages of visitors who will participate in Enjoy Makerspace activities at the Science Museum, Thailand.

2.2 Institutional Agents and Policy Development

2.2.1 Sustainable Development Goals and Thai Government Policy

The United Nations Sustainable Development Goals (SDGs) have developed into a worldwide programme for development and advancement, with the goals intended to address numerous challenges that nations face, including economic, social, and environmental issues. In particular, SDG 4 focuses on ensuring inclusive and equitable education and promoting lifelong learning opportunities for all. This goal is closely related to makerspaces, as they provide hands-on learning opportunities that encourage creativity, innovation, and problem-solving skills (UN, 2023).

Figure 2: Thailand's Vision for 2037 (BIC.moe.go.th, 2023)

In collaboration with the United Nation's sustainable development goals, the Thai government in the year 2018, launched its National Strategy for the year 2018 to 2037, focusing on six elements:

1) Citizen Well-being
2) Economic Growth, National Competitiveness and Income Distribution
3) Talent Development of its Human Capital
4) Equity and Equality
5) Sustainability of its resources
6) Accessibility and government efficiency

(BIC.moe.go.th. 2023)

Goal 3, focusing on the talent development of its human capital, revolved around creating opportunities and accessibility for lifelong learning and development habits. Keeping in mind the need for 21st- century skills, the Thai government developed the following strategic objectives that come in association with Makerspace and modern learning strategies:

1) Fine-tuning the educational framework to cultivate essential skill acquisition.

2) Nurturing the evolution of modern pedagogy
3) Optimising the efficacy of educational administration systems from top to bottom
4) Fostering a culture of lifelong education

(BIC.moe.go.th, 2023)

With these strategic goals and agenda in mind, the Thai government has recognised the importance of promoting science and technology education for its citizens and has supported initiatives that aim to achieve this goal. The NSM Enjoy Makerspace was established as part of this STEM promotional effort (nsm. Th. 2023).

The Thai government formulated several policies to bolster the proliferation of makerspaces across the nation. For instance, the Ministry of Science and Technology has initiated the "National Science and Technology Development Plan". This comprehensive plan endeavours to augment science and technology education, heighten societal cognizance of science and technology and foster the evolution of makerspaces within national borders. Similarly, the Ministry of Education has instigated numerous initiatives designed to endorse experiential learning within academic institutions and advocate the integration of technology within educational practices (Mala, 2020).

Furthermore, the Thai government has undertaken significant measures, with one of the most notable being the execution of the Family Action Plan 2020 – 2022. This strategic initiative symbolises a crucial milestone in the government's concerted efforts to promote lifelong learning and foster a culture of creativity and innovation, demonstrating the government's commitment to enhancing educational practices and opportunities within the nation. The plan's main objectives are to create a happy and violence-free family environment, promote self-reliance through honest careers based on the principles of a sufficiency economy, and raise children in a manner that allows for their overall happiness and development. The family is seen as a key factor in building a high-quality society and reducing negative factors while increasing positive ones and building resilience. Services will be provided to families in need to help them return to stability, and knowledge and skills will be disseminated to the public to promote family development (Opsmoac.go.th, 2020). The strategy of the Family Action Plan is as follows:

The Strategy for Family Learning within the Family Action Plan 2020-2022 seeks to foster a strong and united family unit through the following initiatives ((Opsmoac.go.th, 2020).:

1) Nurturing Family Bonds through Learning and Communication:

a. Empowering families to acquire the necessary knowledge and skills to thrive and grow together throughout the family life cycle.

b. Providing opportunities for parents and guardians to enhance their communication skills and equip them with the tools needed to support their children and engage in positive counselling.

c. Encouraging family members to spend quality time together and strengthen their bond through shared experiences.

(Opsmoac.go.th, 2020).

2) Supporting Family Members Fulfilling their Roles

a. Instilling core values and cultural heritage through positive discipline and modelling positive behaviours for family members, especially parents.

b. Raising awareness and fostering acceptance of gender equality by promoting equitable distribution of responsibilities and roles within the family.

c. Promoting work-life balance by promoting a harmonious balance between work and family life.

(Opsmoac.go.th, 2020).

Therefore, the SDGs and Thai government policy towards maker spaces align with providing inclusive and equitable quality education for all and support the establishment of maker spaces such as the NSM Enjoy Makerspace at the National Science Museum in Thailand. By providing hands-on learning opportunities and promoting creativity and innovation, these initiatives aim to support the development of a knowledgeable and technologically advanced society. While the research policies emphasise enhancing the education policies, the action plan assumes a one-size-fits-all approach to family dynamics. However, the family size can vary significantly in terms of their composition, culture, and structure. Therefore, a much-tailored approach should be adopted and should be necessary, which could reinforce the conventional stereotypes. Furthermore, the policies should also ensure the instilment core values that could respect the diversity among Thai families. Hence, some additional gaps and criticisms could be addressed in terms of Thai educational policies. The findings of this study could be a steppingstone towards addressing these gaps in Thai education, learning, and growth policies.

2.2.2 Thai Education System and National Strategy

This study follows Thailand's National Education Act 1999 (amended in 2002). The education system consists of three types of education outlines the types of education within the system: formal education, non-formal education, and informal education as shown in Table 3

Types of Education	Details
(1) Formal	Formal education defines the objectives, methods, curricula, duration, assessment, and evaluation procedures used to determine it has been completed
(2) Non-Formal	Non-formal education has flexibility in defining its objectives, delivery modes, management methods, duration, assessment, and evaluation. Non-formal education content and curriculum must be relevant, responsive to regulations, and adapted to the needs of groups of learners.
(3) Informal	Informal education enables learners to study independently, based on their interests, potentials, preparation, and chances provided by individuals, society, the environment, the media, and other sources of knowledge.

Table 3: Types of Education

(Source: The Office of the Education Act of 1999, amended in 2002)

Furthermore, Section 23 of the National Education Act of 1999 (amended in 2002) states that education, whether formal, non-formal, or informal, should emphasise "… knowledge, morality, learning process, and integration of the following depending on the appropriateness of each level of education":

1) Self-knowledge, knowledge about the relationship between oneself and society (this includes one's family, community, nation, and the world at large. In addition, knowledge

regarding the history of Thai society, Thai politics, and an understanding of a democratic government under the monarchy.

2) Knowledge and skills in science and technology, as well as knowledge and experience in management and conservation, thereby sustainably utilising natural resources.

3) Knowledge regarding religion, art, culture, and Thai wisdom (including its application).

4) Knowledge and skills in maths and languages, emphasising using the Thai language properly.

5) Knowledge and skills for developing a career and a happy life.

(Source: The Office of the National Education Commission, 2002:10)

This study aligns with the forms of learning previously mentioned above because the NSM Enjoy Makerspace activities emphasise knowledge about oneself, technological knowledge, learning new skills, art, mathematics, and skills in pursuing one's career. Furthermore, this study takes place in the National Science Museum because this is a place of informal learning, and therefore coincides with the aims of Section 25 of the National Education Act of 1999 (amended in 2002, p. 12). This section states that "the State shall promote the running and establishment, in sufficient number and with efficient functioning, of all types of lifelong learning sources, namely: public libraries, museums, art galleries, zoological gardens, public parks, botanical gardens, science and technology parks, sport and recreation centres, databases, and other sources of learning".

Section 28 of the National Education Act of 1999 (amended 2002) states that the essence of the curricula about both academia and professionalism should focus on the human development of knowledge, critical thinking, capability, virtue, and social responsibility, (The Office of the National Education Commission, 2002, p. 12). Importantly, this does not include an emphasis on 21st century skills, which would only enter the national education policy later (Cleesuntorn, 2015). Thus, while the National Education Act does guide the development of NSM activities, as it does for other educational institutions, it is not directly responsible for the emphasis on 21st century skills or the development of STEM interests.

The National Strategy of Thailand (2018 – 2037, p.2) states that the vision of Thailand is to develop into a secure, prosperous, and sustainable country " … following the Sufficiency Economy Philosophy". The National Strategy of Thailand (2018 – 2037, p.2) outlines several goals necessary to manifest this outcome: a safe and harmonious nation, promoting economic growth and wellbeing, social equality, promoting self-empowerment to create competent and happy individuals and sustainable use of natural resources. Six key indicators will be used to evaluate the National Strategy:

(1) "Well-being of Thai people and society".

(2) "National competitiveness, economic growth and income distribution".

(3) "Development of human capital".

(4) "Social equality and equity".

(5) "Sustainable development of national biodiversity, environment quality and natural resources".

(6) "Government efficiency and better access to public services".

(Source: National Strategy Secretariat Office, 2018: 2)

This study addresses the alignment of the goals of the NSM Enjoy Makespace with the third indicator, the "Development of human capital". The NSM Enjoy Makerspace aims to develop knowledge, skills, inspiration, and creativity in visitors participating in the activities therein. This learning can then be utilised to develop their studies or careers and thus contribute to the country's development. This study is an independent investigation of the outcomes of the NSM Enjoy Makerspace's human capital development activities. The strategy for human capital development (National Strategy: 2018 - 2037) emphasises developing Thai people of all ages to have the relevant knowledge and skills necessary to ensure a good quality of life, such as improving physical, mental, and cognitive attributes, promoting social responsibility and public mindedness. This strategy will encourage Thai citizens to become modern innovators, thinkers, educators, entrepreneurs, farmers, etc.

The main guidelines from the Human Capital Development and Strengthening Strategy Are shown in Appendix 1.

2.2.3 Culture in Thailand and Family Learning – Society in Thailand

Thailand boasts a vibrant culture that places a significant emphasis on education and lifelong learning, particularly in science and technology. The Thai government has taken considerable strides in regarding the education and empowerment of its people, with particular focus on family-based practical experiences. In this respect, "NSM Enjoy Makerspace" of the National Science Museum provides an excellent example of such commitment, as it offers a chance for families to engage in hands-on and experiential learning activities connected with Science and Technology (Ratana-Ubol and Henschke, 2015). Moreover, Charungkaittikul and Henschke (2014) argue that Thailand has a long-standing tradition of valuing education and the pursuit of knowledge. According to these authors, the country's citizens are encouraged to pursue scholastic chances to stay well-informed about the newest progressions and technologies (Charungkaittitul and Henschke, 2014). This cultural value is reflected in the government's policies and agendas to endorse science and technology education and deliver hands-on learning experiences for families, of which the NSM Enjoy Makerspace can be considered one. However, as the study of Charungkaittikul and Henschke (2014) took place before the makerspace was developed, their research did not include it.

However, despite the findings proposed by Charungkaittikul and Henschke (2014) and several other researchers, such as Jinanarong et al. (2021) and Binson and Lev-Wiesel (2018) claiming the importance of hands-on learning experiences for families, the ongoing learning process specifically focuses on rote-memory in Thailand. In one of the research studies by Huang et al. (2019) on Thailand's learning approaches, it was revealed that rote learning was a predominant learning principle. Followed across the schools. Furthermore, the findings by Phayoongwong (2015) stated that schools in Thailand had developed new strategies, such as the keyword learning method, which could be effective in memory retention. However, this could harm the creativity of the students and limit problem-solving and practical thinking processes. For example, Jeyaraj (2019) stated in the research that experiential learning might improve the learning skills and communication skills of an individual, which can be beneficial to all three domains of learners – cognitive, affective, and physical and their related skills and abilities such as confidence and self-reflective capability.

Similarly, family interactions via family learning experiences are likely to demonstrate an enhanced impact on individual pursuit. A report of Thai culture by Sungsri (2009) and Richards et al. (2019) highlights the regional context and brings to attention the place of family learning in the education system. Education is regarded in Thai society as both a personal and shared undertaking. The family has an important role to play in nurturing the education of children and the number of opportunities that the government provides for families to take part in interactive learning experiences together is a testament to this fact. Thailand has introduced several family learning activities as examples for practical learning and continuous education culture. The following table shows some examples of such platforms:

Platforms	**Descriptions**
Science and Technology Workshops:	The National Science Museum and other educational institutions in Thailand offer workshops and classes for families to participate in together. These workshops cover various topics, such as robotics, engineering, and computer programming, and provide hands-on learning experiences for families to work on projects and develop their skills together.
Maker Faires and STEM Festivals:	Maker Faires and STEM Festivals bring together families and communities to celebrate creativity and hands-on learning. These events often feature exhibits, demonstrations, and hands-on activities related to science, technology, engineering, and mathematics (STEM) education
Mobile Science Centres	Some organisations in Thailand have developed mobile science centres that travel to schools and communities to bring hands-on learning experiences to families. These centres typically feature interactive

Platforms	Descriptions
	exhibits and hands-on activities that help families learn about science and technology in a fun and engaging way.
Online Learning Platforms	The Thai government and other organisations have also developed online learning platforms to make it easier for families to access educational resources from home. These platforms offer a range of educational resources, including video tutorials, interactive simulations, and hands-on activities, to help families learn about science and technology together. However, executing the program through online system could procure significant implications such as through the engineering and back-end aspects, which, however maker-aces could develop with ease.

Table 4: Family Learning Activities Implemented by Thai Government in Support of Life-long learning.

(Soratana et al 2021; Kanhadiklok, 2013)

Therefore, it can be argued that Thailand's government strongly emphasises education and lifelong learning, particularly in the realm of science and technology. The Thai government's initiatives and programmes, such as the NSM Enjoy Makerspace at the National Science Museum, are a testament to the country's commitment to empowering its citizens through hands-on learning experiences and fostering a culture of continuous learning and growth.

2.2.4 Policies of NSM

According to the NSM Action Plan (cited in nsm.or.th, 2023), the National Science Museum (NSM) in Thailand recognises the crucial role that hands-on learning experiences play in family's education and personal development. As such, the institution has instituted various policies to foster a supportive and enriching learning environment. Some of the noteworthy policies include:

Policies	Description
Emphasis on Experiential Learning	The ideal of the NSM's educational philosophy is that exposure to practical learning activities that ensures the genuine activeness in science and technology. The NSM Enjoy Makerspace is a good example of this concept and hands families a series of tools, equipment and resources to hone their skills and their creativity.
Nurturing Creativity and Innovation	The NSM strongly agrees that individual growth and development are rooted in creativity and innovation. For this purpose, the organization gives families the opportunity to resources and help with the goal of creating and promoting their creative and inventive minds.
Support for Continuing Education	The NSM acknowledges the importance of lifelong learning and have put in place policies that afford all families a chance to access educational aids and assistance during the entire course of their lives. It also includes workshops, courses, online learning tools, and practicum opportunities.
Focus on Science and Technology Education	The NSM is an institution that focuses in science and technology education and its policies have this emphasis. Families are given affordable, interesting, and interactive ways to participate in science and technology, and also to access educational resources and support that will create their competence and knowledge.

Table 5: Policies of NSM for Learning

(nsm.or.th, 2023)

As noted, these policies of the National Science Museum (NSM) in Thailand are aimed at promoting a supportive and enriching learning environment for families, fostering hands-on learning experiences, nurturing creativity and innovation, supporting lifelong learning, and placing a special emphasis on science and technology education (nsm.or.th, 2023i).

2.3 The Concept of the Makerspace

The core concept of the makerspace can be viewed in the words of Davee (2014, p.3) as "as simple as a table or a backyard with sticks, mud, and bricks". Kelly (2013) further elaborated on this definition, which comes in alignment with those suggested by various authors in the field of maker space, stating that it is a place or "centre where people with common interests, often in computers and machining and so on, can meet, socialise and collaborate" (p. 1, cited in Yu, 2016). Moreover, Sheridan et al. (2014) have defined Makerspaces as "informal art, science and engineering development sites where people of all ages merge digital and physical technology to discuss concepts, practice technical skills and develop new products (p. 505)". Therefore, a Makerspace must accommodate a wide range of activities, tools, and materials, associated with the all-round STEM learning curriculum that can enhance the Makerspaces activities. Furthermore, it has been stated that Makerspaces are an educational movement constructed and constructivist in design, influencing the world through inventive DIY projects and education (Max et al., 2023). Makerspaces commonly have a variety of "maker" equipment made available, from "low tech" hammers, chisels, saws, Lego, art supplies, soldering irons, and sewing machines to more "high tech" laser cutters, 3D printers, complex Computer Numerical Control (CNC) computer-controlled machines. Cooper (2013) points out that a Makerspace is not simply a science laboratory, woodwork shop, computer room, or art studio. Still, it is a space that may contain and combine elements found in all of these more familiar facilities.

As Rendina (2015, p. 2) has stated, "Makerspace place where might gather to develop, build, improvise, explore and discover a variety of instruments and materials". This accords with our sense that "everyone is a maker". A Makerspace is an educational zone where readily available materials and technology are presented that, together, act as "catalysts for inquiry" for people of all ages. In our view, then, a Makerspace nestled inside a science museum is a place where visitors of all ages can:

(i) Explore and understand an environment that focuses on "making" and its value.

(ii) Develop skills, imagination, and creativity, and

(iii) Gain enjoyment and inspiration through activities that use resources, tools, and materials.

The rise of makerspace during the 1960s signalled the beginning of a new era of technological and do-it-yourself culture, which was associated with the rise of the science and technology studies (STS) field of interest (Lachney and Foster, 2020). STS was an educational movement that centralised science and technology in primary and secondary education and was based on the principles of "making and doing" as tools for learning.
Around 2010, the focus of the public's attention shifted from technology to science, engineering, and mathematics or the widely known STEM. This increase in interest in STEM was driven by several factors, including an increasing government focus on STEM as a means to economic growth, growing public awareness of information technology and coding, and development and/or cost reduction of common "making" tools such as 3D fabricators (Bilkstein, 2018). This led to the idea of making being widely distributed, compared to its earlier position as a niche hobby that was mainly undertaken by adult technology specialists (Fleming, 2015).

From a constructionist theory of pedagogy perspective, learning is a process that involves being, doing, knowing, and becoming (Laurillard et al., 2013). For instance, Sheridan et al. (2014) argued that learning can be done by making things that can be talked about, explored, and admired. Therefore, in a community that is made up of people working together, learning is happening in a hands-on manner – creating what is called a makerspace. Moreover, Bevan et al. (2014) stated that the goal of a makerspace is to provide a safe and supportive environment for people to explore and develop their skills. Part of what is interesting about this research is how a national museum such as the NSM, in which visitors are not part of the same community, can build ad hoc communities and interact cooperatively to engage in creative play and learning.

As an educational practice, Makerspace draws on a century-long development of pedagogical theory and practical development (Blikstein, 2018). Blikstein (2018, p. 420) remarked that " Progressive educators and constructivist researchers have been prescribing interest-driven, student-centred and experiential approaches for more than a century… scholars have also dedicated considerable attention to the symbiotic relationships between the human mind and external artefacts when performing complex tasks… as well as alternative orchestrations for learning environments such as apprenticeship-based models". (Blikstein, 2018, p. 420). However, the NSM Enjoy Makerspace has a difference compared to the formal educational contexts in which these studies have taken place. Specifically, there is no curriculum or required path within the makerspace, and neither is their peer or teacher evaluation. While there are scaffolded guides for learners, such as suggested projects and exhibition monitors who can help, the makerspace is a much more unstructured learning environment than those promoted under these theories of constructivist learning.

Thus, the work of educators such as John Dewey, Maria Montessori, and Paolo Freire, along with the child psychology theorists Jean Piaget and Seymour Papert, has led to the development of the maker movement as an experiential educational movement. However, several other factors came into play before Makerspace could be established as an educational practice (Blikstein, 2018). These factors included a growing governmental interest in innovation, the increasing prevalence of coding and making it a practice, and the reduced cost of fabrication technologies such as 3D printing, which have facilitated the relatively inexpensive outfitting of maker spaces (Blikstein, 2018). Overall, it can be stated that Makerspace has only emerged as a form of public educational space since the early 2000s, building on "hackerspaces" and "fab labs", which started in the 1980s and 1990s (Blikstein, 2018).

Today, Makerspaces can be found in several contexts, including schools and universities, museums, libraries, collective and shared private spaces, and private commercial spaces (Blikstein, 2018; Tomko et al., 2021). Makerspaces can be outfitted differently depending on their funding, objectives, user base and interests, which will influence what should be (and what is) included in the space itself (Tomko et al., 2021). However, Makerspaces are not always ideally equipped due to resource and budgetary constraints (Blikstein, 2018).

Enjoyment of Makerspace activities at a science museum provides the opportunity for learning by doing and creating something new that can lead to originality and innovation. Nevertheless, more than this: Smith et al. (2013) suggested that Makerspaces are also concerned with the community and connections created whilst individuals work in and around the space. Thus, they suggest that these spaces allow innovation at a community level rather than an individual or institutional level.

2.4 NSM Makerspace, Thailand

The National Science Museum, Thailand (NSM) (2018) is a state enterprise under the Ministry of Higher Education, Science, Research and Innovation, Thailand. The NSM is responsible for developing and managing the following four museums and the Museum of Science Square.

- Science Museum
- Natural History Museum
- Information Technology Museum
- Rama 9 Museum
- NSM Science Square

Its vision is to be a centre of excellence in learning-centre development, management, and allocation to promote public awareness of science. The mission (NSM, 2018) is to encourage a general understanding of science and technology by accruing local wisdom, communicating science, and promoting science learning.

2.4.1 NSM's Museums Exhibitions

2.4.1.1 The Science Museum

The Science Museum (figure 4) has on display more than 250 hands-on exhibits and models of science and technology in everyday life.

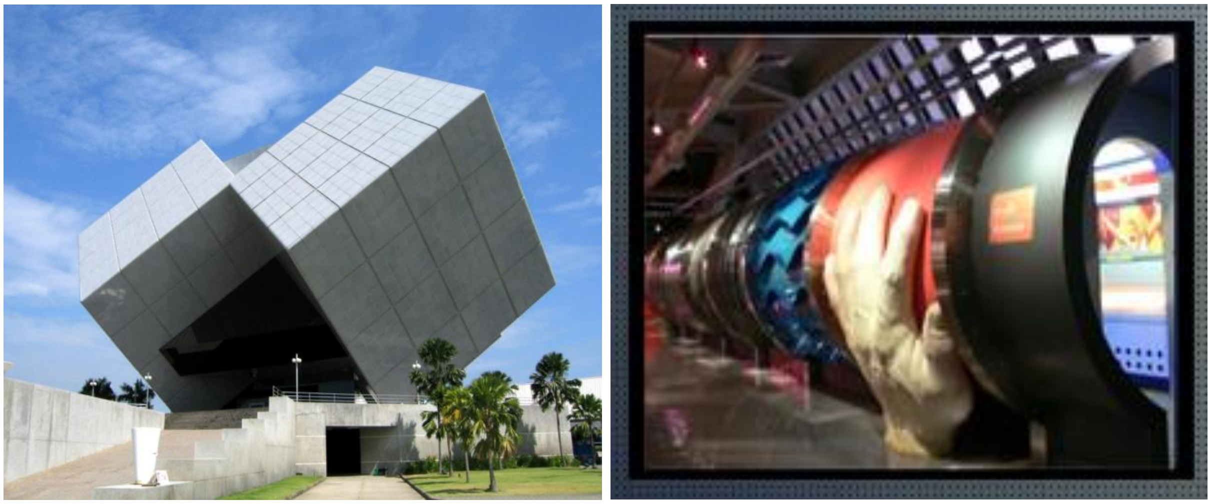

Figure 3: Photographs of the Science Museum

(Source: National Science Museum, Thailand, 2018)

2.4.1.2 The Natural History Museum

This Museum introduces knowledge of the development of species and the diversity of living beings, from single-cell species to the kingdom of animals. Life-sized representations of various plants and animals are displayed, particularly emphasising species found in Thailand. The exhibits cover an area of 3,000 sq.m. It preserves an extensive collection of specimens from nature and is Thailand's main centre for research regarding taxonomy and biodiversity.

Figure 4: Photographs of the Natural History Museum

(Source: National Science Museum, Thailand, 2018)

2.4.1.3 The Information Technology Museum

This Museum includes 9,000 sq. m of exhibits and provides an interactive approach using computer and communication technologies. The exhibits apply the concepts of communication, computing, networks, and IT, demonstrate how innovation and development lead to new results and highlight technical progress in these technologies, encouraging the ingenuity and imagination of youth in the future world.

Figure 5: Photographs of the Information Technology Museum
(Source: The National Science Museum, Thailand, 2018)

2.4.1.4 The Rama 9 Museum

This Museum introduces His Majesty King Bhumibol Adulyadej the Great in his systematic problem-solving approach and the principle of self-sufficiency, which can result in simple but effective solutions to the country’s major problems.

Figure 6: Photographs of the Rama 9 Museum
(Source: National Science Museum, Thailand, 2018)

2.4.1.5 The NSM Science Square

This is located at the Chamchuri Square Building in Bangkok's city centre entertainment complex. The NSM Science Square is oriented to families and children, with its content focusing on new scientific discoveries and technologies via hands-on exhibitions from Thai and foreign organisations.

2.4.2 Education Programs And Activities Of NSM

Apart from museum exhibitions, the NSM offers different educational activities for school students and various public programs for families, children, and adults. Most programs are based on an enquiry - based approach providing informal STEAM (Science, Technology, Engineering, Art and Mathematics) learning experiences to people of all ages. Regarding Education Programmes, the NSM organises various activities related to science, technology, and biodiversity, such as Science shows, Science cultural camps, the Science laboratory, Science rallies, Science competitions, Science outreach and the NSM Enjoy Makerspace.

Figure 7: Photographs of activities of the NSM

(Source: National Science Museum, Thailand, 2018)

2.4.2.1 Science show and drama

The Science shows, and dramas are interactive shows that offer a fun and educational experience covering various science topics such as the: Egg show, Bump show, Music show, Magic show, Bubble show and Liquid Nitrogen show. The shows include demonstrations of exciting scientific phenomena with the opportunity for audience members to become part of the show.

2.4.2.2 Science Cultural Camps

To enrich the scientific minds of youth, the NSM offers overnight activities such as science camps for school groups and individuals, so they can learn how discoveries are made in science and increase their knowledge of science. These camps (run all year round) have particular themes, and such experiences offer young campers the opportunity to gain skills in social interaction and systematic thinking.

2.4.2.3 The Science Laboratory

The Science Laboratory allows individuals to gain experience working in a lab. Those who take up this opportunity gain an understanding of the scientist's work, working with scientific equipment and exploring the scientific world around us. The Laboratory offers two-and-a-half-hour science experiment sessions for school groups or one hour for families, and children learn that science can be fun anywhere, any time.

2.4.2.4 The Science Walk Rally

To encourage fun and challenging ways to visit the museum exhibitions, the NSM invites visitors to join the Science Walk rally programme, offered in various packages for school groups or families.

2.4.2.5 The Science Competition

The NSM collaborates with partners from domestic and international organisations and holds annual national science competitions, including Water rocket competitions, Paper Airplane Folding competitions and Youths Science Projects. Such activities inspire the creativity and imagination of children and establish a more significant forum for those interested in science. The NSM also encourages youth development and engagement in communication science to the community through youth leadership and award programs such as Young Thai Science Ambassadors, Young Thai Science Journalists and the Science Game Developer Award.

2.4.2.6 The Science Outreach Programme

The NSM takes travelling exhibitions and activities to schools and public events. This allows students and children in provincial or remote areas to experience Science in an enjoyable and interactive environment. It also helps bring Science to people's doorsteps and allows the NSM to participate in local school or community activities. Such exhibitions include the Science Caravan, Science at the Mall, and Preschool Science, and the NSM is one of the key partners in the Little Scientists House Project, Thailand, under the Princess Sirindhorn Foundation. In addition, the NSM plays an active role in promoting science learning activities in preschool education and family contexts.

2.4.2.7 The NSM Enjoy Makerspace

The NSM has created space for Makerspaces to promote learning in STEM by using the NSM Enjoy Makerspace and providing an environment and resources for makers to create their work and undertake a particular job or project. The NSM Enjoy Makerspace is one of several iterations of the makerspace concept at the NSM, focusing on the basics of STEM learning. Other iterations have investigated concepts including Art along with Traditional Wisdom, Social Studies, and Sustainability. Each of these iterations of the NSM Enjoy Makerspace has had different exhibits and hands-on activities to stimulate experiential learning in different contexts. In this study, the Makerspace team look to share our best practice of incorporating other elements into STEM by using Makerspace as a platform for enhancing soft skills and raising awareness of Sustainable Development within the Thai context.

2.4.3 Professional Development and National Science Events

2.4.3.1 International Collaboration

The Makerspace team are active members of the museum network and continuously work on various cross-country projects such as:

- Asia Pacific Network of Science and Technology Centres (ASPAC),
- The International Council of Museums (ICOM),
- European Collaborative for Science, Industry & Technology Exhibitions (ECSITE).

Areas of collaboration include exhibition exchange, staff development and research.

2.4.3.2 National Science Events

As an essential arm of the Ministry of Higher Education, Science, Research and Innovation, the NSM Thailand promotes the public's understanding of science. The NSM collaborates with various institutions (including the Ministry of Education, universities and research institutes) to organise national and international scientific events, such as the Science Avenue for National Children's Day and the National Science and Technology Fair.

2.5 The NSM's Enjoy Makerspace

The NSM Enjoy Makerspace at the National Science Museum provides an environment and relevant resources for makers undertaking a particular project. The space promotes a creative atmosphere with walls of tools, a machine corner and small exhibitions displaying past STEM learning projects. The spaces are designed so participants can access the resources (including tools) they need to realise their ideas, with the assistance of a museum "educator", if needed. In addition, assistants are present to guide participants in using the tools and machinery where necessary. Possible activities at the NSM Enjoy Makerspace are similar to those identified by Cooper (2013) as being suitable for elementary school makerspaces, including:

(i) Cardboard construction.
(ii) Prototyping.
(iii) Woodworking.
(iv) Electronics.

(v) Robotics.
(vi) Digital fabrication.
(vii) The building of kinetic machines, and
(viii) Textiles, sewing, knitting and origami.

Thus, the defining features of “technology” within a Makerspace like this are broad indeed.

Figure 8: Photographs of the NSM Enjoy Makerspace rooms at the Science Museum.
(Source: Science Museum, Thailand, January 2020.)

2.5.1 Universal Design for the Makerspace

According to the introduction and the chapter that outlines the purpose of this thesis review, everyone can be a Makers through NSM Enjoy Makerspace at the Science Museum. It is important to understand the Universal design of the Makerspace and the guidelines that create an effective Makerspace to explore visitors motivation, knowledge, skills, inspiration, and creativity through the NSM Enjoy Makerspace activities at the National Science Museum, Thailand. It is necessary to realise that the location and scale of the space will dictate the types of programmes that can be undertaken, which will also impact the curriculum of the makerspace activities. There is also a certain tension between the desire to provide a free and open space for learners to engage creatively (the ideal of the makerspace) and the fact that many of our visitors, particularly younger visitors, require instruction on how to use equipment safely and may benefit from providing creative prompts of how they can explore specific concepts. For this reason, the equipment of the NSM Enjoy Makerspace is available for visitors to use as they wish within the bounds of safety, but there are also several activity stations operational at a

time, which provide materials and guidance for a more specific project, including scientific background, technical information, and instructions on how to do certain tasks.
Understand the knowledge and plans for universal design for the Makerspace for Education system and the National Strategy.

1) **Design for Flexibility**

Because the project's scope, materials, and media used, team size and structure, and power and computing requirements vary per project, room flexibility created additional opportunities. Firstly, understanding the curriculum and the place and deciding on a schedule for the mobile project tables makes it possible to reconfigure the room as needed as stated by Layton, Ostermiller and Kynaston (2020). So, to enable movable workstations, electrical power was supplied by overhead cord reels or at the room perimeter, with wireless data available throughout. Plumbing, which is required for some of the activity stations, was restricted to the perimeter. These principles of flexible design have made it easier to adapt the NSM Enjoy Makerspace exhibition space to different types of activities.

2) **Storage and exhibition space are critical.**

Access to equipment and materials must be convenient for participants in the Makerspace activities, although the presence of mixed-age users and possibly dangerous tools necessitates supervision and continuous monitoring. Storage space will be required for the equipment and tools, and space will be needed to display the completed projects.

3) **Pollution control is essential.**

Many Makerspace activities produce dust, airborne particles, fumes, or odours which must be controlled to ensure user comfort and protect the health and safety of participants. Pollution control systems include Dust control for wood-cutting operations, an exhaust for metal-or laser-cutting operations, isolation and negative pressure for 3D printers, and adjustable "snorkel" hoods for soldering necessitate specialised planning systems to protect individuals and maintain their health and safety.

4) **Good sound control**

In personal learning, isolating and creating sound barriers to privacy is customary. While room acoustics are essential in any learning environment, they are especially critical.

In Makerspaces, where tools and equipment generate noise that can impede communication. Overall, reasonable sound control is vital to prevent noise contamination of adjacent learning spaces beyond providing the workplace is a clean and comfortable environment.

5) **Occasionally required to work outside for shop purposes.**

From the perspective of critical 21st-century career skills, the Maker movement is about teaching and learning focused on student-centred inquiry, not the project done at the end of a learning unit, but for the actual vehicle for learning. A Makerspace is not limited to a scientific lab (STEM), a woodwork shop, a computer lab, or an art room; and may indeed incorporate features from all these different spaces. Makerspace activities create a sense of design and innovation, promoting a culture of creativity and collaboration. The significance of the Universal Design for a Makerspace is that it enables people with a broad range of abilities, reading levels, learning styles, languages, cultures, and other characteristics to participate in the activities within the Makerspace. Moreover, the design adapts to a broad range of individual preferences and skills. For example, a museum allows a visitor to choose to read or listen to a description of the contents of a display case board.

Universal Design is the idea that spaces and products should be intentionally designed to be accessible to as many people as possible. This idea grew out of disability access, creating or modifying facilities and equipment to make them more accessible to disabled people, including wheelchair users, those with limited imagination, and people who are hard of hearing. Most of the time, accessible solutions in the built environment are installations, which are added on after a design has already been planned and added to the curriculum.

Finally, education skills for Makerspaces are collaborative workshops in which children and adults gain practical hands-on experience creating and building projects using new technology and learning new skills. Such spaces provide a flexible environment where learning is made physical by applying Science, technology, math, art, and creativity to solve problems, use skills and build things.

2.5.2 Development of 21st Century Skills

While the NSM Enjoy Makerspace is open to people of all ages and abilities, its specific focus in the design of exhibits and activities and provision of equipment and materials is the development of children's 21st century skills. The definition of 21st century skills is "a broad set of knowledge, skills, work habits, and character traits…." and "… related terms including applied skills, cross- curricular skills, cross- disciplinary skills, interdisciplinary skills, transferable skills, transversal skills, noncognitive skills, and soft skills, are also used to refer to the knowledge and skill "… associated with 21st century skills". (Glossary of Education Reform, 2016, p.1). Furthermore, it is noted that the skills are a set of abilities children need to develop for success in their information age (Thoughtful Learning newsletter, 2020). Stauffer (2020) suggested that 21st century skills are abilities that today's students need to succeed during their lifetime.

Skills
"Critical thinking, problem solving, reasoning, analysis, interpretation, synthesising information"
"Research skills and practices, interrogative questioning"
"Creativity, artistry, curiosity, imagination, innovation, personal expression"
"Perseverance, self-direction, planning, self-discipline, adaptability, initiative"
"Oral and written communication, public speaking and presenting, listening"
"Leadership, teamwork, collaboration, cooperation, the facility is using virtual workspaces"
"Information, and communication technology (ICT) literacy, media and internet literacy, data interpretation and analysis, computer programming"
"Civic, ethical, and social-justice literacy"
"Economic and financial literacy, entrepreneurialism"
"Global awareness, multicultural literacy, humanitarianism"
"Scientific literacy and reasoning, the scientific method"
"Environmental and conservation literacy, ecosystems understanding"
"Health and wellness literacy, including nutrition, diet, exercise, and public health and safety"

Table 6: The 21st Century Skills by Glossary of Education Reform

(Source: Glossary of Education Reform, 2016: p1)

Based on some notable statements provided in Table 6 above, the table can further be summarized thematically, and it can be noted that the overall learning tends to include (i) learning and innovation skills, (ii) digital literacy skills, and (iii) career and life skills – as grouped below.

1. Learning and innovation skills	**2. Digital Literacy Skills**	**3. Career and Life Skills**
1.1 Knowledge and skills 1.2 Problem Solving 1.3 Communication 1.4 Collaboration 1.5 Creativity Skill	2.1 Information Literacy 2.2 Technology Literacy	3.1 Flexibility and Adaptability 3.2 Self-Direction 3.3 Social Skills 3.4 Productivity 3.5 Leadership

Table 7: The 21st Century Skills Adapt from the Partnership.

(Source: Partnership for 21st Century Skills (2015))

Several other categorisations of 21st century skills can be seen in Appendix 2 (Trilliing and Fadal, 2009) and Appendix 3 (Adapt from Partnership for 21st Century Skills (2015). However, in terms of the existing skill-set, it can be granted that the 3 main skills cannot only provide a long-term growth direction, but also, improve the future growth span of the children. First, it can be noted that makerspace activities tend to foster a critical thinking process, which can enhance the capability of the children to develop creative solutions and promoting a mindset of continuous improvement Furthermore, makerspace activities, such as those that complement STEM learning (discussed in the following sub-section), can contribute to cultivation of curiosity and exploration of future innovative direction. Second, the NASM makerspace activities are often integrated with digital technologies, such as iPads, as well as the use of presentation and computers for ease and efficiency of managing the teaching practices. Hence, makerspace activities expose children to range of technologies, including 3D printers, coding platforms, and digital design tools, and through such hands-on experiences, children acquire technology literacy skills, enabling them to understand, use, and leverage technology for learning and problem-solving. Finally, the third skill-set includes career and life skills. Participating in the NASM makerspace activities can contribute to the children learning to navigate uncertainties, adjust to evolving project requirements, and embrace the iterative design process, which can form as an invaluable skillset in an era of rapid technological advancements and diverse career paths. Furthermore, the makerspace activities also tend to foster collaborative projects, which can provide opportunities for children to develop leadership and social skills, whereby, allowing them to communicate effectively, delegate tasks, and contribute as team members.

2.5.3 STEM

STEM refers to a cluster of related disciplines – Science, Technology, Engineering, and Mathematics – at the forefront of modern innovation and educational policy (Shu and Huang, 2021). There are different ways to characterise STEM learning. First, STEM learning can refer to improved knowledge and understanding of the subject matter of STEM disciplines (Rau, 2017). For example, STEM learning under this definition could relate to learning to use a particular technology, code or use other information technology (IT) tools, or learning specific scientific and mathematics techniques. Second, STEM learning can relate to learning about the STEM professions, how STEM knowledge can be applied to solve real-world problems, and about STEM as a career choice (Francis et al., 2019). This research uses an integrated definition of STEM learning, incorporating knowledge and understanding of the STEM disciplines and the role of STEM disciplines and careers. This incorporates multiple perspectives on STEM learning that the NSM Enjoy Makerspace activities may impart.

2.5.4 Resources of Makerspace activity

2.5.4.1 Learning from the Makerspace Activity

The activities I describe below are “set pieces”. Family groups visit the Museum and come to the NSM Enjoy Makerspace to participate in the activities. In the directed Makerspace activity sessions, all the resources are pre-organised: including the organised materials necessary to do particular projects, the relevant tools and also the handbooks. Educators and assistants are on hand, with the Educator leading and generally overseeing the particular activity, while the assistants encourage families understanding, answer questions, and help solve any problems family members may encounter as they participate in the activity. Each family group shares one set of tools and materials between them. The handbook offers more information and understanding for the family to learn during the workout or take away to study at home or school.

Figure 9: Photographs of an Educator, an Assistant, and a toolkit
(Source: Makerspace @ Science Museum, Thailand, January 2020.)

For the NSM Makerspace team, an essential ingredient of maker spaces is that they are communal. While discovering, making new things, or improving existing products is necessary, a key goal on the same line is learning, collaborating, and sharing.

2.5.4.2 Museum Educators or the Maker Educator

Brahms and Crowley (2016) have indicated that educators who are actively participating in museum activities are often referred to simply as museum educators. They are crucial in fostering a love of learning and a lifelong connection to culture and history. Through their know-how and motivations, they bring exhibitions and artefacts to life, making them pertinent and reachable to visitors of all ages and backgrounds. Brahms and Crowley (2016) also further note that museum educators also engage actively in helping visitors comprehend multifaceted thoughts and historical events, providing context and historical perspectives that expand visitors appreciation of the exhibits. Furthermore, Hsu et al. (2017) state that museum educators are also responsible for developing and implementing educational programs, workshops, and special events. They work together with curators and other museum staff in creating interesting experiences that are in line with the Museum's mission and objectives. They also cooperate with schools and community organizations in order to extend the resources of the Museum to different groups and to create valuable learning process. Added to this invaluable resource, the museum educators, as Williams (1989) suggested, must have strong communication and interpersonal skills and a deep understanding of the Museum's collections, exhibits, and themes. They must also be familiar with current education theories and best practices and have experience working with various audiences, including children, adults, and families. In line with a past study by Brahms and Crowley (2016) and Hsu et al., (2017), it can therefore be clarified that, museums have an intricate role in the development of new learners interest and educating them about the unique subjects of learning. Furthermore, authors such as Williams (1989) also attribute museum educators as the subject of the museum, that can help facilitate social interactions. Therefore, museum-based practices can foster social interaction, which can comprise of stakeholders including family, friends, general museum staff, security, and even those who are indirectly involved. The museum as a whole is a full-scale experience.

In addition to that, the normative groups that the learners travel with, for instance, parents, friends, colleagues, also tend to have a significant impact on the learning experience in museums. When families visit museums, parents are key educators as well, as they are the primary people who will be responsible for the children's learning experiences. This would be directly related to how much or how well they interact with their children in the museum process. Research by Falk (2006) and Yanowitz and Hahs-Vaughn (2016) has demonstrated that a parent's perception of their child's potential to learn in museums, as well as their level of participation in these experiences, significantly stimulates the development of both the child and the family's overall learning. Additionally, Downey et al. (2010) state that several parents see museums as spaces where their children can nurture and reinforce their collaboration skills. However, Andre et al. (2017) argue that various obstacles can delay parents from supporting their children's learning in museums, such as a lack of knowledge about the content, unmet expectations, and the perceived role of the parent in their child's museum experience. Along with this, not all parents have the time and financial background to be taking their children to the museums. Although the NSM is not costly in any manner, the time taken away from work is often a serious issue in Thailand, where the current status indicates increasing expenses while the minimum wages continue to remain the same.

2.6 Experiences of Learners within the Makerspace

2.6.1 Hands-On- Learning and Engagement

Hands-on learning, or experiential learning, is a highly effective and memorable method of acquiring knowledge and skills, as several scholars have suggested their significance in the development of memory. For instance, a child is more prone to learning a process or stages through an activity, based on touch, smell, sight and if possible other elements as well. A combination of all, as such, can lead to improved learning ability and improvement, as suggested in the study by Kaltman (2010). Contrary to other forms of learning, such as passive learning, which involves only listening via the sense of hearing or observing via the sense of sight, hands-on learning requires active participation and physical interaction with the subject matter.

When looking into this based on the context of a makerspace activity within a national science museum, hands-on learning can be facilitated by using tools, materials, and technology to create and build projects. Gerstein (2019) states that this approach allows visitors to apply their newfound knowledge and understanding of science concepts tangibly, nurturing a deep appreciation and preservation of the information or knowledge that is being actively embedded into their brains. This active engagement intrinsic to hands-on learning is more effective concerning knowledge preservation and enables visitors to make meaningful connections between the concepts they learn and actively apply them to real-world scenarios. This type of learning can also increase motivation and interest in a particular subject, as visitors have the opportunity to experience the concepts, they are learning first-hand. Hands-on learning can develop skills such as critical thinking and problem- solving skills, as visitors must dynamically occupy themselves with the materials and technology provided to create and build their projects. In a makerspace environment, visitors can cooperate with others, leading to a sense of community and shared purpose, further improving the learning experience from a holistic perspective (Galaledin et al., 2016).

Another element often seen within the context of undertaking activities via the makerspace concept is engagement. This has been discussed in the earlier paragraph; however, engagement can be understood in a multitude of ways. For instance, here the scholar wishes to demonstrate the engagement of the stakeholders, especially the family. Family learning is the cornerstone of this thesis, and therefore elaborating engagement from this principle is ideally important for understanding makerspace significance. Authors such as Kumpulainen and Kajamaa (2020) indicated that engagement is a vital aspect of any museum experience and can be referred to as the level of involvement and interaction visitors have with the exhibits and the Museum as a whole.

Engagement in a makerspace activity within a national science museum is crucial in ensuring visitors have a memorable and educational experience, as when undertaking hands-on activities, interactions with families and a learning environment, only lead to developing memories that stay. The Museum needs to offer a hands-on learning and make its environment interactive, entertaining, and intellectually engaging to boost engagement. This can be achieved through giving the visitors access to different tools, materials, and technology that will allow them to make some projects, that would in turn promote deeper understanding of science concepts.

Besides, other authors like Koh et al., (2018) have contended that engagement can be enhanced through allowing visitors to undertake projects together, thus, leading to a sense of shared community and purpose, as this will allow them to be more open to the idea of collectivism, an essential element of Thai culture and also group dynamics.Sharing knowledge although, a benchmark in the cultural aspect of collectivistic societies, is also a foundation for educational institutes regardless of the cultural foundation. For instance, I can argue that in the United States and the UK where the predominant culture is based on individualism, this may be detrimental to the proper progression and development of the learning community and academic institutions. In such an environment, knowledge should be shared, and it should not be withheld to a personal success on its own, but a group accomplishment. Therefore, such collaborative learning skills acquired from makerspace can lead to a greater sense of camaraderie and enhanced learning opportunities, as visitors can learn from one another and build on each other's strengths and ideas. Finally, engagement can also be increased by creating an environment that is visually appealing and aesthetically pleasing, with exhibits and displays that are both educational and engaging. By providing visitors with a visually stimulating environment, they are more likely to be captivated and engaged in the museum experience, leading to a deeper appreciation and understanding of science concepts.

2.6.2 Collaborative Flow

2.6.2.1 Challenge(S)

Within the context of a collaborative flow, a concept that authors such as Admiraal et al., (2011) and Richter et al., (2006) have indicated to be a process in which learning is undertaken, is not one on their own, but a dynamic interaction between participating stakeholders, such as students and teachers, or students, educators, and their parent. Ultimately, collaborative flow is when a group of people interact actively with one another, allowing them to reach the target, which in the case of makerspace should be the accomplishment of the activity. However, within such a context, challenges are possible. As with all collaboration, even in the field of learning and education, challenges are there. For instance, authors such as Nakamura and Csikszentmihalyi's (2002) study on the concept of flow defined perceived challenges as an element that tends to reflect actions or events that are beyond one capacity to approach and implement. The concept of perceived challenges in the study by Nakamura and Csikszentmihalyi (2002) has been further elaborated in research papers by Rudland et al. (2021), wherein the perceived challenge is recognised as both potentially beneficial and/or detrimental to the learning process. Rudland et al. (2021) defined challenges as any event or action that is beyond the capacity of an individual's skill and expertise to conduct. Numerous research papers on the domain of "challenge" and its impact on learning have emerged in the past decade, with theories like stress, Vygotsky's theory on challenges and cognitive development, and

Mezirow's theory of transformative learning process. Commonly these theories suggest that some form of dissonance (stress or challenge) is required to foster growth in the learning process. However, these theories identify different types of dissonance (stressors), such as what needs to be known or what has been previously known. Rudland et al. (2021)'s findings further state perceived challenges in the context of experiential learning episodes. The findings suggested that environmental factors, including authentic environment and authentic tasks, were better-controlled factors that positively impacted learning experiences. The scope of this thesis orients much more towards the concept of "experiential learning". Radovic et al. (2021) stated that authenticity, reflection, and collaboration are key pillars of experiential learning. This research looks at flow and flow learning as the first state of experiential learning that learners may encounter.

2.6.2.2 Flow and Flow Learning

Flow can be described as a state in which an individual fully engages in an activity as an end in itself (Nakamura and Csikszentmihalyi, 2014). This psychological state often occurs during "Flow Learning", a type of educational experience that aims to bring learners into this optimal state of immersion and focus. In a Flow Learning environment, educational structures are designed to match the key conditions that facilitate a flow state. A flow state can occur in any activity in which conditions are balanced to include "perceived challenges, or opportunities for action, that stretch (neither overmatching nor underutilising) existing skills; a sense that one is engaging challenges at a level appropriate to one's capacities [and] clear proximal goals and immediate feedback about the progress that is being made" (Nakamura and Csikszentmihalyi, 2014, p. 91).

In Flow Learning, educators carefully calibrate tasks and challenges to align with the learner's current skill level, thereby maximising the likelihood of inducing a flow state. The curriculum may include self-paced modules, interactive challenges, and real-time feedback mechanisms that enable students to adjust their actions and strategies following their progress (Sohl-Dickstein et al., 2009). The goal is to create an environment that supports the natural occurrence of flow states.

Furthermore, as noted by Nakamura and Csikszentmihalyi (2014, p. 91) "the subjective flow experience is characterised through" intense and focused concentration... the merging of action and awareness... loss of reflective self-consciousness... a sense that one can control one's actions... distortion of temporal experience... [and] experience of the activity as subjectively rewarding". Flow learning seeks to make these elements not only inherent features of the flow state, but also targeted outcomes. As outlined by Admiraal et al., (2011), in educational environments, promoting such characteristics, result in improved learning outcomes, higher satisfaction and more intrinsic motivation to be involved in the learning process.

The idea of Flow Learning philosophy is said to be especially favorable for STEM in the works by Rossin et al., (2009) and Zollars (2017) where the subject's challenge and complexity call for a deep level of engagement and focus. The use of Flow Learning methods in STEM curricula may make the students be more enthusiastic, comprehending, and retaining the material for longer periods. Magyarodi et al., (2013) claimed that these features define the concept of subjective flow measurement.

According to their findings, this form of assessment is composed of scales that measure a person's concentration, engagement, and sense of time while engaged in an activity. In educational settings the capturing of these subjective flow metrics gives educators a good feedback about the result of their ways of teaching, in turn, leading to an optimal learning experience. Therefore, in the flow experience, a person becomes totally absorbed in the activity they are doing.

Furthermore, the idea of flow can be woven in as a consonance to experiential learning and family learning as it is closely related in all their systems. It generally, from the opinion of the author of this dissertation, becomes family learning, when more than one member of the family partakes in a similar activity or knowledge-gaining process. Therefore, this can lead to the formation of a shared sense of engagement and focus among family members, strengthening the collective learning experience. Whether it's working on a DIY project or exploring a museum or a makerspace activity, the flow state can turn these activities into more meaningful and enriching experiences. Similarly, in experiential learning environments, which are often less structured than traditional classrooms, flow can serve as a natural bridge between learner autonomy and focused, efficient learning. As Nakamura and Csikszentmihalyi (2014) and Schweder and Raufelder (2021) stated, the flow experience is an integrative learning concept that connects cognitive and emotional learning practices.

The concept of “flow” can also be integrated with the concept of the Makerspace Learning Process. At the core, the principles of flow and Makerspace Learning align almost perfectly. Makerspaces, by design, allow learners to set their own goals and pace, offering immediate feedback through the tangible results of their work. Csikszentmihalyi and Csikszentmihalyi (2014) state that this autonomy and immediate feedback are key components that facilitate a flow state. Makerspaces have inherently been established as a flow process that orients towards experiential learning practices. One study in a university art Makerspace noted that the learning process through the Makerspace was inherently a flow activity, in which makers became fully involved with the making process itself (Sweeny, 2017).

A study in Finnish craft classes (a forerunner of Makerspaces, which was project-oriented) also reinforced the importance of flow as a facilitative state for learning (Jaatinen and Lindfors, 2019). The research highlighted that the nature of such classes, free-style, project-based, and student-led, induces flow naturally. This fact points to the likelihood that learning environments created for flow can produce an enjoyable and successful learning situation. Jaatinen and Lindfors (2019) observed that the students usually became fully immersed into the process of learning though they were indifferent to the final object. Another study investigating learning in Makerspaces by Schweder and Raufelder (2021) also highlighted the significance of flow. Schweder and Raufelder (2021) demonstrated in self-directed learning in a Makerspace that the flow experience was positively associated with persistence, interest, and elaborative strategies, so it was a core determinant of learning. This is to say that flow is not simply a byproduct of such settings, but an integral part of pedagogic design. There are many ways to integrate flow principles into pedagogy or the very design of the Makerspace that will improve student engagement and outcome. Hence, it could be suggested that a flow experience in a Makerspace, is a determinant of both engagements in the activities themselves, as well as the level of learning that takes place within them.

2.6.2.3 Collaborative Flow – Family Learning/Team Learning

Admiraal et al. (2011) state that collaborative flow refers to a harmonious state of collaboration between individuals or teams that results in a heightened level of productivity. This phenomenon occurs when individuals or groups work together towards a common goal with a shared sense of purpose, a clear understanding of roles and responsibilities, and an open flow of information, ideas, and feedback. In this environment, individuals actively strengthen the team based on what each individual is best at, that is each individual's strengths. This then allows the improving outcomes and increasing efficiency. Similarly, in family learning, collaborative flow fosters shared learning experiences, promoting teamwork and constructive feedback among children and adults. Engaging in a DIY project together, for instance, allows families to divide tasks, share ideas, and strengthen bonds through meaningful interaction and learning (Brahms, 2014). Therefore, maker spaces benefit from collaborative flow, enabling individuals and teams to work effectively together. Therefore, what we can see is that in such community-driven workshops, individuals bring their distinctive skills and viewpoints to the table, leading to an improved sense of collaboration. This suggests that group-based project learning may also be more effective than individual learning, although of course this effect is not infinite; previous research suggests that small groups of two to five members are optimal for group learning (Pai et al., 2015). Collaborative flow also promotes creativity, innovation, and opportunities for social and emotional growth while fostering a sense of belonging and shared purpose.

2.6.2.4 Immersion

Immersion is a concept related to flow, but it is slightly different in the extent and definition of what it incorporates. Immersion is a cumulative state of cognitive and emotional involvement in the context (such as a game world) (Jennett et al., 2008). The first step of immersion is engagement, where learners become involved in the learning process (for example, learning how to use the tools). In engrossment, the learner becomes emotionally invested in the activity and its outcome. Finally, immersion is a state where the individual gets completely immersed in the activity while the external world fades into the background. Total immersion, therefore, is characterised as a cognitive and emotional state in which the learner becomes completely involved in the activity to the extent that they lose awareness of external space and time (Jennett et al., 2008). Thus, immersion is a similar final state to flow, but it is understood as a cumulative effect of cognitive and emotional interaction between the individual, activity, and environment. There has been less study of immersion as a cognitive state in the Makerspace than flow, as it has mainly been investigated in the context of gaming following Jennett et al.'s (2008) initial definition. Thus, this research offers the opportunity to investigate how active experiences can ensure child development in Makerspace and how they influence learning between families, collaborative learning, and the development of creativity.

The research also investigates the extent to which the Makerspace activities at the NSM Enjoy Makerspace facilitate immersion. This is a key point because, as Jennett et al. (2008) explained, total immersion is relatively rare and fleeting and requires careful alignment of all activities. Therefore, visitors are expected to experience different levels of immersion and may not become fully immersed in the activity.

2.6.3 STEM Learning

Some research has been undertaken on how science museums and Makerspaces influence STEM learning among visitors. Francis et al. (2019) conducted a visitor assessment of the London Transport Museum, a technology and engineering-oriented Museum focused on the London transport system. They found convincing evidence that the visitor experience at the Museum enhanced their understanding of and desirability of STEM as a career path (Francis et al., 2019). The main focus of Makerspace are centralized STEM activities, which are essentially the practical approach of technology and engineering disciplines, materials sciences, and mathematics (Heredia and Tan, 2021). This way of learning enables the participants to build STEM knowledge by watching, trialing and doing, and making them modify and work with designs in order to get what they have designed (Heredia and Tan, 2021). Making activities may also encourage what one group of authors termed computational thinking, or the abstraction and decomposition of problems and the design of solutions for these problems (Herro et al., 2021). This could imply that even when Makerspace activities do not use information and computation technologies (ICTs), they are still designed to promote a problem-solving approach used in STEM (Herro et al., 2021). Makerspaces also promote an understanding of the concept of STEM design, a problem-solving approach that uses the material world to resolve problems (Vongkulluksn et al., 2021). Through this process, Makerspaces promote design and growth mindsets among users, encouraging experimentation, creativity and innovation to solve problems proactively (Vongkulluksn et al., 2021). These studies show that science museums, generally, and Makerspaces specifically, promote STEM learning. However, these studies do not clearly articulate how the learning conditions within Makerspace facilitate this learning process, which this research investigates. In summary, there is strong evidence that Makerspace as a learning environment promotes STEM learning - both learning about STEM as a discipline and learning STEM material and approaches to thinking and problem-solving. This raises the question of what factors most influence the STEM learning outcome.

2.6.4 Family Learning

While family learning is usually an intergenerational process that involves children and adults learning together. However, a small number of courses can be adult-only. These include programs that support children's development at school. Due to the increasing number of policies supporting family learning, the impact of this activity on children and adults is becoming more widely acknowledged. This publication aims to provide a framework for tracking the progress of children and adults in family learning. It also allows providers to record the stories of their student's progress (Borun et al., 1996).

Family learning is a collective process. Hilke (1988, p. 12) indicated that families "… have been in the business of learning together for many years. Dropped into the museum environment with new and different objects drawing their attention on all fronts, family members unconsciously draw on these learning resources to structure their free-ranging behaviour. Their behaviour, so deceptively chaotic on the surface, actually reflects a complex, well-balanced interweaving of personal and cooperative agendas to learn".

Specific behaviours are associated with family learning (Borun et al., 1997). These behaviours are interactions between family members and exhibits, including asking and answering questions, reading texts (silently or out loud) and explaining or discussing exhibits (Borun et al., 1997). Activity-oriented museums, such as children's museums and Makerspaces, can be extended to engaging with and completing hands-on activities (Brahms and Werner, 2013; Lewin, 1989; Marsh et al., 2019).

However, not all families display family learning behaviours (Wood and Wolf, 2010). For example, some parents may closely control what children interact with, while others stand back and do not interact as strongly (or at all) (Wood and Wolf, 2010). Family learning also interacts with staff facilitation, which can be positive or negative depending on the specific situation (Pattison and Dierking, 2012). Thus, family learning behaviour is complex, dynamic, and dependent on pre-existing family learning practices. However, it should be noted that this learning behaviour has been almost entirely described from the perspective of childhood learning facilitated and guided by adults, and very little is known about the role of family learning in the development of knowledge or learning practices by adults. This is an interesting imbalance in the literature which, while out of the scope of the current study, could be of interest for future researchers.

Children's museums, such as the National Science Museum of Thailand, are designed to facilitate family learning by arranging the environment to facilitate early learning rather than preservation (Lewin, 1989). This means that the objects and activities are selected for learning interest for the target age group; that the Museum is "hands-on"; that it is arranged by space rather than time, allowing visitors to explore until they are finished and that learning occurs in a specific context (Lewin, 1989). However, family learning can also occur in other environments, such as outdoors (as in nature walks) (Zimmerman and

McClain, 2016). Thus, while family learning is a special concern of museums, it is not unique to the museum environment.

Makerspaces seem to be ideal environments for family learning, though this has been little studied. One group of authors investigated the role of Makerspaces as a tool for early childhood education (ECE), which occurs between two and five years (Brahms and Werner, 2013). They argued that the fundamentally interactive approach of Makerspace facilitates family learning because most activities require adult assistance. They recommend designing the Makerspace to promote interaction between family members within the setting, and to create habits of learning that carry on outside the makerspace environment (Brahms and Werner, 2013). These recommendations for designing Makerspaces to promote collaboration between family members have also been taken up by other authors, who have proposed a formalised model of pedagogy for Makerspaces as a teaching tool (Marsh et al., 2019). Marsh et al.'s (2019) pedagogical model calls for a design that encourages both agency and the sharing of funds of knowledge between family members. Therefore, Makerspaces (at least, if designed to promote interaction and exchange of knowledge, following the principles of learning) are likely to serve as places of family learning. The current research is an opportunity to observe family learning in practice within the Makerspace environment and investigate how family learning occurs and its relationship to STEM learning.

The research context of family learning is complex, particularly since it is relatively new compared to older theories of learning (Ellenbogen et al., 2004). The study of family learning is also challenging because it is fundamentally an interaction process rather than a defined outcome (Ellenbogen et al., 2004). Furthermore, it inherently depends on existing identities and relationships within the family unit, which are not necessarily visible from the outside (Ellenbogen et al., 2004). This complexity has led to the use of methodologies such as observations and multi-method approaches, which allow for investigating family learning processes in different ways (Ellenbogen et al., 2004). These methodologies are also used in the current research, as explained in Chapter 3.

2.6.5 Learning, Emotions

Literature suggests that activities within makerspaces evoke emotions and have a lasting impact on an individual's lifelong learning journey. The following are some key literatures that have identified the changes in the learning capabilities that are derived from emotional responses.

Vongkulluksn et al., (2018)	Vongkulluksn et al. (2018) state that at the heart of maker spaces is the excitement and sense of accomplishment that comes with completing a hands-on project. The journey of taking a mere idea and transforming it into reality instills a sense of pride and self-worth influenced by the time spent. Engaging in hands-on activities allows individuals to see the tangible results of their efforts, empowering them and fostering a positive outlook on their abilities. Moreover, Makerspaces are designed to be nurturing environments that foster social connections and collaboration. The interactions between individuals with similar interests and passions give rise to a sense of community and belonging. This sense of community provides individuals with a support system that encourages personal growth and development.
Oliver et al. (2021)	Furthermore, Oliver et al. (2021) argue that maker spaces offer opportunities to hone problem-solving and critical thinking skills. The hands-on projects often present challenges that require creative and innovative thinking. Overcoming these challenges gives individuals a sense of pride and accomplishment while developing their problem-solving and critical-thinking skills. As a result, makerspaces may promote lifelong learning. The hands-on learning experiences provide individuals with a solid foundation for their future personal and professional growth. The skills, knowledge, and experience gained in maker spaces can be applied to various real-world challenges, contributing to their ongoing learning journey (Abrams, 2018).
Soomro et al. (2022)	Soomro et al. (2022) indicated in their study that makerspaces' collaborative and supportive atmosphere promotes creativity and

	innovation. The freedom to experiment and explore new ideas nurtures an individual's innovative thinking skills and fosters creativity.

Table 8: Key Empirical findings on emotions and learning

What can be noted from the findings above is that these skills and experiences, in turn, become valuable assets on their lifelong learning journey. Based on this, makerspaces offer a range of emotional and learning benefits that contribute to an individual's lifelong journey. The sense of pride, accomplishment, and community, the development of problem-solving and critical thinking skills, the promotion of creativity and innovation, and access to resources and support all play a crucial role in fostering personal and professional growth. Whether individuals seek new growth opportunities or develop new skills and knowledge, makerspaces offer a supportive and collaborative environment that can provide a valuable and meaningful learning experience (Jaatinen and Lindfors, 2019). However, some questions remain about the impact of emotions. One of these issues is the development of emotions over time and whether the duration of the makerspace experience matters. Another issue is that all the research that was reviewed for the study only focused on positive emotions, such as pride. However, the nature of the makerspace experience is such that there *are* negative emotions involved, such as the frustration experienced with a project failure or when others cannot help the learner understand a project. This is an important gap in the literature on experiential learning and makerspaces and should be addressed within further studies as well as here.

2.7 Empirical Review and Theoretical Foundation

2.7.1 Constructivism Theory, ESD and A Model of the Makerspace for Education

Through the research findings and the literature review, we learnt about the concept of constructivism, the concept behind a Makerspace, the structure and activities of the Makerspace at the NSM, Thailand, and continuous comprehensive evaluation are impacted by the theory of construction, a learning theory and a model for maker education and to the goal of learning, learning through practice. However, the empirical studies have not addressed the underlying theoretical foundations of learning within the makerspace.

The purpose of this review is to investigate the theoretical foundations of the makerspace and set out a theoretical framework for the study.

Jean Piaget (1929, 1937, 1954, and 1970) was a learning theorist and an early proponent of the concepts of agency and inventiveness that we now value in the modern maker movement. This study strongly agrees with the idea that, like Piaget (1929, 1937, 1954, 1970), Constructivist professionals pose questions and problems and guide people to help them find their answers. Similarly, this study favours user-generated learning models that would challenge traditional schoolings, such as passively receiving canonised ideas from adults and teachers, and the expert as a venue for raising museum activity, for the social disruptions of innovative thinkers instead of well-trained consumers, much in the same way that Paulo Friere (2005, originally 1970) viewed education as a means of enlightenment, not of oppression.

Constructivism theory says that knowledge is dynamic and not static (every individual can create new knowledge); based on previous experiences (Fosnot 2013). The primary sources that create knowledge are 1) social, 2) language and 3) cultural interactions (environmental interaction), while the local environment and circumstances also play a significant role in constructing knowledge (Fosnot, 2013).

The essential learning components are making sense of things and developing the ability for abstract thinking, observation, and work (Fosnot, 2013). One of the most critical issues is that children learn through experience, making and doing things, experiments, reading, discussions, asking, listening, thinking, reflecting, and expressing themselves in speech, movement, or writing, both individually and with others (Mughal and Afzar, 2011). The early years provide the foundation for language, physical dexterity, social understanding, and emotional development that the child will use for the rest of their life (Fosnot, 2013). The theory of constructivism argues that many people (perhaps most people) learn best through hands-on experimentation (Fosnot, 2013). The research and anecdotal data strongly support the argument that Makerspace students learn best when they engage with instructional content and actively participate in the class, which is very significant. Makerspaces offer active, creative, collaborative, interdisciplinary experiences and the opportunity to learn skills, such as innovation, and social disruption, in which real-world problem-solving helps with critical thinking and boosts confidence, which is significant in understanding the learning experience. Despite having limited research in the field of innovation and social disruption, this could expand into future literature.

In conclusion, Makerspace activities foster design thinking, innovation, and experiential learning, as well as promote social-emotional skills, which are necessary to be sustainable. At the same time, a few programmes have adopted an integrative and cross-disciplinary approach and avoid repetitive activities.

2.7.2 Empirical Review

The concepts of learning explored in this literature can be firmly distributed and recognised as active learning, group (collaborative) learning, and cooperative learning. Empirical research papers have commended that each type of this learning process conveys a positive learning experience, granting a higher cognitive learning experience. Considering such, empirical literature that reviews the cognitive impact of active learning education, group learning as a collaborative strategy, and cooperative learning in a family setting has been further reviewed.

2.7.2.1 Active Learning Education

Active learning is a model of “instruction” that allows learners to pursue learning through discovery, processing, applying, and synthesising information together. The concept of active learning was initially acknowledged in the research paper of the 1950s by Bloom (1956), which stated that individuals could learn through various means. However, active learning should be combined with engaging content, reflective behaviour, and ideal objectives. Furthermore, cognitive psychologists have portrayed that active learning procedures can improve the levels of processing of information and allow faster recollection of information (Craik and Lockhart, 1972). Active learning, combined with elaborated materials requiring in-depth interpretation of information, can strengthen the cognitive mindset’s deeper encoding of information.

Furthermore, active learning has been adopted as a pedagogical paradigm, wherein the concept of active learning can be merged with a learner-centred teaching behaviour and patterns and allows a rather "meaning-making" experience, rather than providing a non-meaningful experience to the student/learner (Cherney, 2011). Mutual correspondence between peers and teachers can enhance active learning, as it helps students develop their concepts and develop long-term links that will make the subject more understandable. It also helps them understand why information is important and useful, and if they can make sense of the content and are motivated to exert more effort, they will perform better (Cherney, 2011).

The research papers by Ulutas and Kanak (2018) stated that family involvement is based on children's behaviour. The study indicated that collaborative learning could improve the learning process when considering family involvement. In the concept of family involvement, the study by Ulutas and Kanak (2018) stated that family members involvement could be acknowledged as a scientific learning process, specifically for children 5 to 6 years of age. The study by Ulutas and Kanak (2018) clarified the findings indicating that children between 5 to 6 years of age with family involvement are expected to have an improved complex subject like "science". This has further been confirmed in other research papers, including Henderson and Martin (2004) and Rego et al. (2018). These past papers on cooperating learning and family improvement have been defined to improve academic performance. Considering the need for peers or colleagues in the group learning process, it can be further recognised that active learning in a group is a much more effective learning process than individual active learning.

2.7.2.2 Group Learning as a Collaborative Strategy

A research paper by Wyk and Haffejee (2017) infers that collaborative or cooperative learning is often used interchangeably in pedagogical domains, wherein co-op learning strategies (learning in a group) can increase student learning activity. Dillenbourg (1999) states that collaborative and cooperative learning environments, with a small group of 2 to 5 members, can increase student activity and can be applied to teach lifelong skills, motivation, and teamwork. This concept is further enhanced when applied in the context of adult learners. The study by Bonwell and Eison (1991) stated that adult learners generally perform better when engaged in collaboration in a small group, which imminently triggers an active learning process. In addition, the study by Kubo et al. (2011) and Kaufman et al. (2000) states that group work as a collaborative approach can allow students to apply additional motivation in practical situations. Combinedly these papers have outlined the benefits of collaborative learning, including improving student retention and developing their interpersonal skills.

Students lives, such as their self-image, study habits, and satisfaction with the subject. The study by Rego et al. (2018) further indicated that cooperative learning programs, family education programs, and service-learning programs would improve the students cooperating learning experiences, promoting improvements through practical approaches and the ideal synthesis of information. A further research paper by Altintas and Yenigul (2020) states that active learning education using cooperative learning and family involvement can further be improved in a museum setting. Research papers by Altintas and Yenigul (2020) further found that using museum-based learning can improve cognitive learning through collaborative training experiences. It can also help them develop higher achievement and positive relationships with peers from different cultural backgrounds. The combined student retention, interpersonal skills, positive relationships with peers and cultural background substantially benefit the learners (Wyk and Haffejee, 2017).

However, in addition to group learning, it can further be stated that group and cooperative learning can be enhanced through family involvement. More specifically, using groups like peers and colleagues can be more specific in including family members during the learning experience.

2.7.2.3 Past Empirical Findings and Learning Methods in Connection to Makerspace

The following table evaluated some key learning strategies mentioned by key authors in the past that would be vital in analysing the research results. These authors provide theoretical models of learning that are used in the discussion (Chapter 4) to explain and understand the learning environment and how the NSM Enjoy Makerspace enables certain types of learning.

Lave and Wenger (1991)	Lave and Wenger (1991) in their seminal work on "Situated Learning: Legitimate Peripheral Participation", discuss the importance of learning as a social practice and stress the significance of learning through participation within communities. They argue that knowledge is fundamentally situated in the social and cultural contexts in which it is used. Applied to the NSM Enjoy Makerspace, this concept underlines the importance of its community-oriented setting. In this environment, family visitors not only engage with materials and tools, but also interact with other participants, share ideas, and learn from others, promoting a social, cooperative learning process.
Murrell and Claxton (1987),	Murrell and Claxton (1987), based on Kolb's theory of experiential learning, highlight the importance of the learning process. They propose that learning is effective when learners take the learning experience as an activity but not an object to consume, i.e. learning process in not a product. Such point of view is directly connected with hands-on, participating approach in the NSM Enjoy Makerspace. These visitors participate in projects, they use scientific concepts, make errors and learn from these errors, which is a dynamic learning process unlike the traditional instructions.
Vygotsky (1978)	Vygotsky as site for his sociocultural theory to cognitive development especially the concept of Zone of Proximal Development (ZPD). He posits that learning occurs when people are helped to perform activities a little above their independent capacities. This idea is clearly seen in the NSM Enjoy Makerspace, as knowledgeable instructors and assistants who give required support to the visitors so that they can tackle tasks

	which are otherwise difficult for them. A scaffolded learning experience nurtures the skills and information retention rate of the visitors and thus creates a learning conducive environment.
Deci and Ryan (1985)	The self-determination theory was formed by Deci and Ryan (1985), in which they argue that autonomy, competence, and relatedness are basic human needs, and when they are fulfilled, they give rise to self-motivated and quality engagement in activities. In the context of the NSM Enjoy Makerspace, these needs are met by offering autonomy in project selection, fostering competence through hands-on learning and accomplishment, and encouraging relatedness through familial and community collaboration. These elements contribute to a learning environment that naturally motivates visitors to engage and learn.
Pellegrini and Smith (1998)	Pellegrini and Smith (1998) highlight the vital role of play in learning, suggesting that it serves as a mechanism for exploration, hypothesis testing, and problem-solving in a fun and relaxed manner. This perspective resonates with the NSM Enjoy Makerspace's approach to making learning enjoyable. By integrating play into scientific exploration and invention, the makerspace transforms the learning experience into an enjoyable journey, easing the path to understanding complex scientific concepts.

Table 9: Past Key Authors

2.8 The Conceptual, Philosophical, and Environmental Makerspace at a Science Museum

The literature review which was conducted in response to the research questions suggests that the following may be observed in the investigation of the NSM Enjoy Makerspace.

1) Anyone of any age can participate in experiential learning. The activities and subsequent learning outcomes can be integrated into other academic, educational, and professional fields.
2) Organised learning within the NSM Enjoy Makerspace should improve participants skills, knowledge and experience.
3) As a result, these activities should provide a learning experience for participants. Therefore, it can be identified because of the NSM Enjoy Makerspace activity on developing skills in the 21st century that are interesting and can be further developed in the future and the ability to be sustainable for social increase.

By incorporating activities and engaging in these fun Makerspace activities and learning, this study conceptualises learning as an activist project by using the notion of "extensive learning" on transformation and creation (Stetsenko, 2017). Prioritising practitioners' articulations of learning over academic explications of theory was an attempt to invite a more multi-voiced approach to expansive learning in the shared activity. This principle corresponds to the subject of the modern learning era. Several theories about self-learning or learning from practice, such as constructionism or Constructivism, believe that knowledge and intelligence exist in all people. Hence, creating a suitable environment for learners to find answers and act independently. The research findings with the main ideas associated with constructivism and constructivism show that community-to-community building interactions and shared normative frameworks are important for developing the NSM Enjoy Makerspace activities and learning outcomes.

An academic makerspace with a conceptual activity in the area museum, dedicated to tools and people to facilitate functional and inspiring making culture intergraded, is characterised by openness, creativity, learning, design, and community. This non-traditional learning environment has immensely increased in popularity and investment in the last decade. These are learning resources from the old era, which focused on the input of knowledge to learners, so they may not answer the question of self-learning. Because knowledge can be obtained by using technology, they need experience the most. The concept of a learning resource called makerspace was born to cater to innovators who want to become professionals more than the school.

Community, Space, Tools, Makerspaces are primarily made up of community, space, and tools. According to The Library as Incubator Project (2012), “Makerspaces are not always established out of a particular collection of materials or spaces, but rather out of a community mindset of engagement, collaboration, and development”. Collectively, designers of Makerspaces seem to agree that community is ultimately what moulds and sustains them (Baichtal, 2011; Britton, 2012), and then from the study and research found that the nature of management comes from the basics, following the theory and conceptualisation of cognitive and social constructivism, which gave rise to constructivism. There is an identity factor based on social development.

Finally, tools are the resources present in maker spaces necessary to engage the community in the making. Typically, these resources are informed and driven by community needs. According to Papert (1991), educators should guide learners through the production of knowledge rather than transferring knowledge to learners. Hence, the pragmatic nature of constructionists lends itself well to theorists in designing learning environments. From the research question, organising learning with NSM Enjoy Makerspace aims to increase skills, approaches, and concepts that are in-depth and broad to affect the relationship between the characters. Conceptually, all participation, the environment, and resources can be applied. In addition, some principles and theories help develop effective learning activities, answering theoretical, practical, and practical questions, which can be sold widely to international markets. This is the real benefit.

Further, Papert (1991) asserts that educators should guide learners through the production of knowledge rather than transferring knowledge to learners. Hence, the constructivist’s pragmatic nature lends well to theorists in designing learning environments.

Over the last few years, libraries, museums, and community centres have opened "Makerspace" for everyone to build knowledge, be creative, and have fun, and this can translate into significant equality for low-income groups to learn outside the box.

As a result, several challenges must be resolved to achieve the research question:

1) The activity theoretically contextualises the three facets of Makerspaces (community, space, and tools) using constructivist-based situated cognition and sociocultural learning theories.
2) In its most basic form, constructivism asserts that meaning can be created; this idea is a point of convergence for constructionist and multiliteracies theories.
3) The individuals' experiences are distributed across social interaction and practise for the best practice and funning activity to learn.
4) Support learning through design experiences.
5) Assist members in developing their interests.
6) Foster an emergent community of learners, and
7) Fosters a climate of respect and trust.

Piaget (1956) proposes that learners gain knowledge through personally meaningful experiences. He also states that knowledge "is constructed and reconstructed through direct interaction with the environment" (Kafai and Resnick, 1996, p. 26). On the other hand, Vygotsky (1978) proposes a more socially based constructivism. He claims that knowledge is socially and culturally constructed, mainly through language. Science experiments and learners then internalise this knowledge to practice outcomes, and future research has discussed the continuous development of the subject. Kafai and Harel (1991) argue that as the making process advances, learners spiral deeper into their interests in a way that is unique to make, rather than just using new media and technologies (Harel, 1988; Peppler and Kafai, 2007). These different perspectives on the experiential learning process suggest that it is an iterative process of environmental and social interaction, through which learners become gradually more active and engaged

2.9 Conceptual Framework

Based on the above structure, the summary-based conceptual framework is indicated in the figure below. This conceptual framework explains how activities are developed and how they contribute to the learning process. The methodology of how the makerspace activity is conducted and its outcomes are presented in the subsequent chapters.

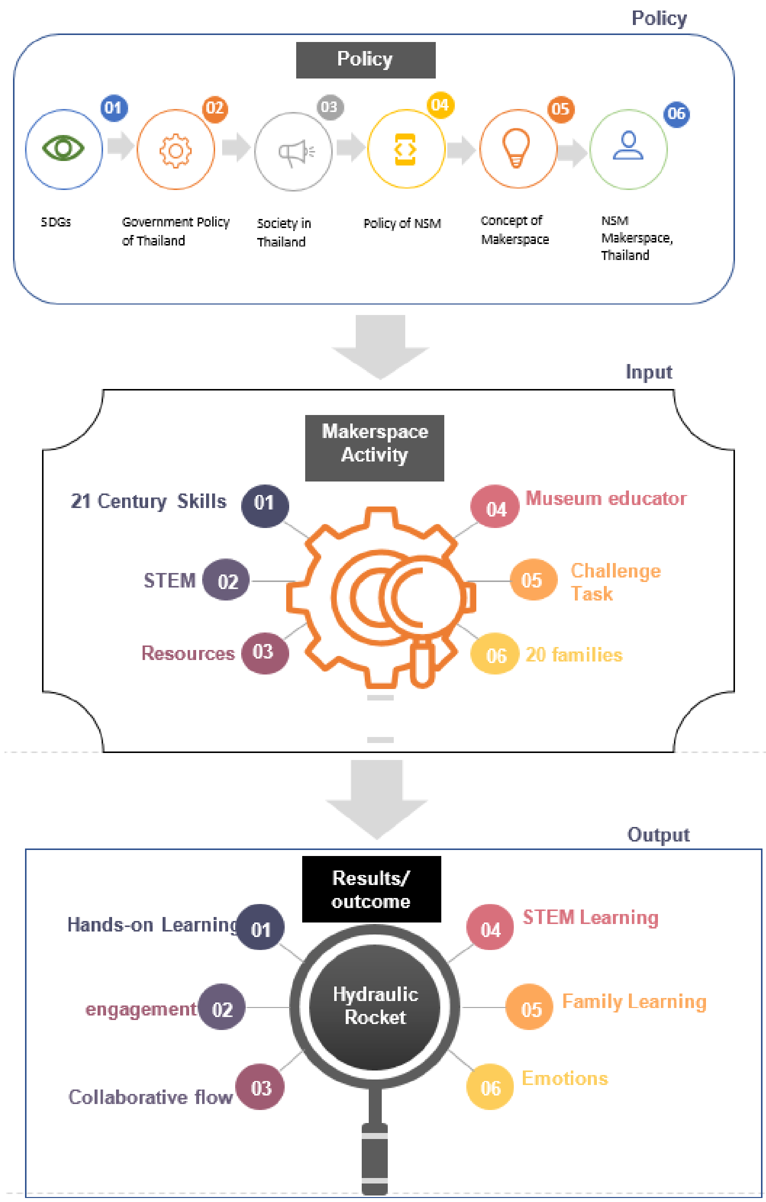

Figure 10: Conceptual Framework

Based on the conceptual framework above, the following figure is the family flow learning outcome, whereby family flow learning falls in the core, which is motivated by makerspace, STEM learning, family learning and collaborative flow. Makerspaces naturally lend themselves to hands-on, creative learning experiences. When families engage in a Makerspace, they not only share physical space but also share a mental and emotional “flow” state. In this scenario, the individuals or subjects in the process are then immersed in a project collectively like a singular unit. The family becomes one. This then involves sharing ideas, and even teaching one another, which leads to mutual learning and problem-solving.

This can be particularly powerful when joined with STEM disciplinarians, as these interdisciplinary subjects often require a combination of logical reasoning along with creativity and innovativeness. As a result, family members are motivated to integrate their strengths while collectively contributing to the success of a project. In addition to this, as noted in the figure above, family learning is another dimension that feeds into Family Flow Learning. The home is often the first place where children are exposed to learning, and parents or caregivers play a pivotal role in shaping a child’s attitude towards education. When Family Learning is transferred to a Makerspace or STEM-focused environment, it elevates the experience by introducing new challenges and knowledge areas that families can explore together. As noted earlier, even in this context the act of learning is no longer a singular or individual-based objective, but more or less a mission of the group.

Lastly, integrating the last element which his collaborative flow, which then demonstrates the collective state of “flow” where everyone in the group is highly engaged and working synergistically. The dynamics of Collaborative Flow can be quite powerful in a family setting, amplifying the benefits of being in a flow state individually. When everyone in the family is mutually invested in a task and experiencing flow, learning becomes more effective and memorable. All of this is illustrated in the following figure. Although STEAM is not the primary focus of this present thesis, it would be intriguing to see the benefits it may bring about in future studies.

2.10 Research Gap

A review of past literature has indicated that the NSM Enjoy Makerspace stimulates an experiential learning environment for the audience/guests. More specifically, in an environment like NSM, children with their family members can stimulate experiential learning and a family learning experience. Furthermore, these antecedents can trigger learning experiences based on "immersion" and "flow". A higher degree of engagement can be achieved by combining family and experiential learning.

Although this relationship remains speculative, it is a useful framing device for the current study. Actions and activities executed through makerspace, like on-site presentations or parent-children's activities, could enhance the learning experiences for the children. Although this can be theoretically inferred, it was found that there is a lack of empirical research in this field, more specifically in the field of NSM Thailand.

In addition to this empirical gap, there is scarcely available literature that reviews factors that encourage all-age family members to engage in NSM Enjoy Makerspace. Furthermore, the relationship between engagement, environment, resources, and outcomes is scarcely reviewed in this field. Considering such, this thesis attempts to cover this empirical gap by performing a multi-method, collecting data using interviews and close-ended questionnaires and analysing via bricolage strategy.

CHAPTER 3: METHODOLOGY

3.1 Introduction to The Chapter

In the previous chapter, the study's conceptual framework (Figure 11) set out the process that would be executed in this research. Based on the conceptual framework, this chapter attempts to highlight the process of the research conduct, specifically elaborating on how the NSM Enjoy Makerspace was investigated to examine these phenomena (the concepts of family learning, experiential learning, flow and immersion, and STEM learning) and the propositions that potentially exist between them. Hence, this research used a multi-methods approach incorporating questionnaires, site observations, and interviews to explore the family visitor experiences and learning outcomes from engaging in the NSM Enjoy Makerspace activities. The reasons for selecting this research approach are outlined, along with the definition of the population, sampling techniques, and data collection processes. Furthermore, the approach to ensuring the reliability and validity of the paper is presented in this chapter. Data analysis techniques used to concern the quantitative and qualitative data obtained from the study will be outlined. The chapter concludes by discussing the ethical considerations central to the research design.

3.2 Aims of The Study

As identified in the first chapter of this thesis, this study aims to investigate the experience of family visitors participating in making activities in the NSM Enjoy Makerspace at the NSM, Thailand. Based on this, the following objectives are addressed:

- To develop family visitors learning through NSM, Enjoy Makerspace activities at the National Science Museum, Thailand.
- To identify the factors that encourage family visitors to learn as a maker through NSM Enjoy Makerspace.
- To study family visitors learning outcomes through NSM Enjoy Makerspace
- To explore family visitors' motivation, knowledge, skills, inspiration, and creativity from NSM Enjoy Makerspace by focusing on family learning, experiential learning, flow and immersion, and STEM learning.

3.3 Research Focus

This study aims to investigate how family visitors from different age groups learn through the NSM Enjoy Makerspace activities in Thailand. In addition, it seeks to identify and describe the factors that encourage learning within the facility. This is the first study to examine how all-age family visitors learn in the NSM Enjoy Makerspace, emphasising the nature of STEM learning and the experiential learning approach. In addressing this and the objectives mentioned above, the following research questions are answered after this thesis:

- How is immersion experienced in the NSM Enjoy Makerspace?
- How do family visitors learn from the NSM Enjoy Makerspace activity?
- What factors encourage family visitors to learn with the NSM Enjoy Makerspace activity?
- What Family visitors motivations, knowledge skills, inspiration, and creativity are derived from NSM Enjoy Makerspace?
- What are the family visitors learning outcomes as a maker through NSM Enjoy Makerspace?

3.4 Target Audience of the Findings

The findings of this study are expected to be beneficial for various stakeholders, including the community, the NSM makerspace museum, the academic division, and from the personal perspective - the scholar herself. In the context of the community, the insights gained can contribute to a more enriched learning environment, potentially fostering a more educated and informed citizenry. For the NSM makerspace museum, the study's outcomes could provide a foundation for refining exhibits and programs, thereby enhancing the visitor experience and educational impact. Being that this study orients towards exploring the educational process or, more specifically, the role of experiential learning and educational process on children's learning and growth - this in-depth exploration could illuminate nuanced aspects of experiential learning, offering a well-rounded perspective and enable the development of more effective learning strategies and methodologies. The findings of this study could enhance the understanding of key factors that educational institutions and teachers should consider. Moreover, the academic division could utilise the findings to streamline curricula, Integrate Innovative learning approaches, and foster an environment conducive to holistic student development. Further details on the significance of the findings are presented in chapter 5 of this study.

3.5 The Planning and Research Design

3.5.1 Research Philosophy and Approach to Theory Development

Methodological literature has stated that it is imperative to define the beliefs of the researcher and the approach adopted toward theory development. Firstly, a research philosophy is defined as the researcher's beliefs, specifically reviewing how a specific problem can be approached and reviewed (Pham, 2018; Mack, 2010). The methodological literature by Saunders et al. (2019) states that research can adopt several philosophical beliefs, including positivism, interpretivism, and pragmatism. While positivist inquiry tends to use statistical and numerical analysis, interpretivism more typically focuses on a text-based analytical approach. Unlike either of the approaches, a pragmatic belief stands that any type of research finding is based on the practicality of the research. In terms of this study, I have adopted the use of a pragmatic paradigm. For instance, if using a positivism paradigm, this study on makerspace would be limited only to using close-ended questionnaire, such as surveying the children and the parents. This limitation drives the need to identify and adopt the third paradigm, which is the pragmatic paradigm. A pragmatic belief intimates that the study's approach must be practical and justifiable regardless of whether numerical or non-numerical research is approached (Jordan, 1996). Believing that the world is not in absolute unity, the pragmatism paradigm suggests that the concept of natural science, phenomenological knowledge, and the relationship between two or more factors can be explored using a mixed approach, or the most suitable approach. This study adopted pragmatism as its research philosophy because of this flexibility, as the research was concerned with different aspects of the museum experience that could not be reconciled with either purely positivist or purely interpretive paradigms. For example, while some aspects could be measured objectively, observations of interactions and the learning experience are inherently subjective. Therefore, it was better to place an emphasis on how best to answer the research questions, rather than stringent application of philosophical assumptions. The rationale for using pragmatic research is based on several key factors, including (i) methodological flexibility, (ii) balancing objectivity and subjectivity, and (iii) open-minded inquiry. A review of the table is presented as follows:

Pragmatic Factors	Link to Research Study
Methodological Flexibility	Pragmatism allows for a mixed-methods approach, combining both quantitative and qualitative methods providing a comprehensive understanding of the multifaceted dimensions of family learning in the makerspace. In the context of the NSM Enjoy Makerspace study, this flexibility is crucial as the research involves various aspects, including learning outcomes, interactions, and experiences.
Balancing objectivity and subjectivity	The study involves both objective elements (e.g., measuring learning outcomes) and subjective elements (e.g., observing and understanding the participants' experiences). Furthermore, the paradigm philosophy acknowledges that various aspects of reality – which includes the reality of the review of the learner's experience, as well as the experience of the family/parents.
Open-minded Inquiry	Pragmatism encourages an open-minded inquiry into research problems, emphasizing the importance of selecting the most suitable methods to answer specific research questions. In the context of the NSM Enjoy Makerspace, where the learning environment is dynamic and multifaceted, the pragmatic approach allows the researcher to adapt and choose the most effective methods for exploring different aspects of family learning.

Table 10: Employing Pragmatic Research in Makerspace Research

As such, the approach to theory development employed in this paper is abductive. Conventional methodological literature states that there are two approaches to research, including (a) inductive and (b) deductive. According to Walsham (1995), an inductive approach refers to the process of generating theory through preliminary observations, which can then be tested. On the other hand, a deductive approach is defined as testing pre-generated hypotheses in the context of a specific scope (Simon, 1996). However, new research papers have adopted the abductive methodology to use a set of quantitative or qualitative observations to derive the likeliest and most plausible explanation of a specific set. The abductive approach corresponds to the utilisation of the interpretivism paradigm, which allows the use of premises in developing and interpreting theoretical concepts, while, aiming to develop a grounded framework for the research. Considering such, this paper develops relevant analytical and conceptual frameworks by using empirical research based on past literature reviews and attempts to acquire premises (data) through an interview-based approach and "close-ended" questionnaires. Considering such, this paper adopts the use of an abductive approach. As presented in Figure 11 of this paper, the conceptual framework was presented. Using the conceptual framework as a guide, the findings of this study have further been explored.

3.5.2 Research Method

The main research approaches that could have been used in this study included quantitative, qualitative, and multimethod approaches. Quantitative research uses statistical analysis of standardised numerical data, while qualitative research uses non-statistical techniques to analyse non-standardised data, such as text (Creswell, 2014), while qualitative research aims to study a phenomenon through the use of non-numerical and text-based analysis, with an approach that is open-to-interpretation. The mixed-methods approach combines quantitative and qualitative data streams, which can be combined in different ways (Creswell and Clark, 2018). For example, Creswell and Clark (2018) have suggested that the application of both quantitative and qualitative analyses is within the capacity to be applied to diverse research queries or to furnish disparate viewpoints on identical research inquiries. These methods could also be harnessed in the development and verification of theories, or to quantify and elucidate outcomes, as noted by Creswell and Plano Clark (2018).

This rendered multi-method research a highly adaptable approach that offset the strengths and shortcomings of both qualitative and quantitative methodologies provided more illustrative detail than quantitative exploration and enabled the testing of relationships, a feature not present in qualitative research (Clark and Ivankova, 2015). Therefore, when considering the execution of a mixed-method strategy, the scholar had already noted that this study is going to utilise more than two methods to ensure a wide variety of data is collected, which can be more effective at answering research questions of different types. Here, the research questions focused on both individual experience and broader outcomes, which made it useful to investigate the questions from different methodological perspectives. The scholar also assumed that there are different fragments of information that were anchored within each other and could be harnessed to address specific research queries, as noted from the research question, and aims addressed in chapter 1 of this paper and chapter 3 introductory sections.

Although mixed-method research was not the original plan of the scholar, throughout the project and all the data that were collected it was the most logical selection. Given that this study's research questions address different phenomena, including relationships between factors, learning outcomes, and learning experiences, the multimethod approach was the best choice for the study. One of the initial rationales for choosing a mixed-methodology was its capability to negate the limitations of using a mono-method, such as, having a solely close-ended survey questionnaire based, or a solely interview based research. This use of mixed methodology, therefore, provides me with the freedom to explore individual experiences and broader outcomes, requiring different methodological perspectives. Thus, the utilization of both quantitative surveys (close-ended questionnaires) and qualitative surveys (interviews), the study aimed to collect a wide variety of data that could effectively answer different types of research questions. In addition to that, the study is also complemented with the use of observational data, which is the outcome of success and failure of completion of the project in the Makerspace activity.

In the proposed research onion, Saunders et al. (2019) stated that researchers are required to select the right strategy that guides the data collection process. The research onion presented by Saunders et al. (2019) indicates several strategic approaches toward research, including experiments, case studies, grounded theory, archival research, and surveys. In this study, I have used quantitative surveys (close-ended questionnaires) and qualitative surveys (interviews). Other approaches like case studies or archival research require an analysis to be “secondary” in nature, as these strategies require reviewing data from past papers. Experimental research has not been performed in this study, as it does not concern testing changes in the behaviour of the respondents but rather studying the existing behaviour of the respondents. Considering such, this study emphasises collecting numerical/statistical data using a close-ended questionnaire and text-based data using a “qualitative” open-ended questionnaire.

However, the multi-methods approach does have several weaknesses that have to be considered. These weaknesses include the potential difficulty of integrating qualitative and quantitative findings from different research approaches (Plano Clark and Ivankova, 2015). In addition, it can be difficult to clearly define the “end” of multimethod research (Creswell and Plano Clark, 2018). While I have acknowledged these limitations, the challenges they presented fit readily within the design choices made. This study adopts the use of data triangulation and a bricolage methodology that allows the integration of findings from the qualitative and quantitative results. In this paper, the bricolage-based methodology has been further enhanced with the depiction of figures and illustrations, allowing the presentation of conclusive findings for the research.

3.5.3 Time Horizon

Researchers can approach studying a single sample for an elongated period or study a group of different samples representing a specific population to procure a specific behaviour (Saunders et al., 2019). This implies the use of either a longitudinal (prior research) or a cross-sectional (latter) time horizon. A cross-sectional time horizon, according to Saunders et al. (2019), would only require studying sample groups once, and therefore, a broader group sample size is required for this purpose. On the contrary, longitudinal research would require recording, analysing, and reviewing the change in the behaviour of a single or more samples across different times. In this study, the nature of the setting and participants precluded the use of longitudinal research. Specifically, there was no way to anticipate or control a particular family's return to the NSM Enjoy Makerspace - while many visitors did revisit the space regularly, others came only once. This meant that longitudinal research, which relies on repeated observations, was not feasible. Considering such, this paper employed a cross-sectional time horizon.

3.6 Population & Sampling

The population of interest for this research was visitors to the NSM Enjoy Makerspace exhibition and activities therein at the National Science Museum, Thailand. Visitors come to the NSM Enjoy Makerspace throughout the year, in different contexts such as family groups, school groups, and independent learners. The research incorporates observations that took place over different times across 2022, including weekdays, weekends, and holidays, and at different times. However, as the main focus was on family visits, most observations took place outside school hours (afternoons, weekends, and school holidays).

There are three patterns common to the NSM Enjoy Makerspace visitor groups. Most visitors are family groups including younger and older children and/or teenagers, parents or other adult guardians, and grandparents. People may also visit as part of larger groups (typically school groups) or individually. Due to this research being concerned with family learning, visitors in family groups were selected as the inclusion criteria for this research. Similarly, the exclusion criteria for the sample group included non-family visitors of NSM, such as lone adults and school groups. However, I was not restrictive in what was considered a "family", including any small group with older and younger members that were not institutional visitors. This meant that "families" included traditional nuclear families (parents and children), but also extended families (grandparents, aunts and uncles, children), older and younger siblings, non-family adults in caregiving roles (e.g., nannies), and mixed groups with unrelated children accompanying family members. The only rule for inclusion of a family group was that there had to be at least one obvious adult (aged 21 and over) in the group, for ethical consent reasons. The main exclusion rule for families was related to children's ages, as a group with only children under 5 would be excluded to allow these young children to focus on learning play rather than research. The primarily rationale for the exclusion also stems from the lack of adequate awareness and understanding of the children in terms of conducting the makerspace activity, and therefore, only children that were age of 5 and above and were willingly participating in the makerspace activities were focused and observed in this study's content.

Participants were divided into four approximate age groups: children (aged 5 to 12 years), teenagers (aged 13 to 20 years), adults (aged 21 to 60 years), and elder adults (aged 61 years and over). These age groups were selected because they are relatively easily identified since much of the research was based on observation, not direct interaction.

While younger children, including those below the age of 5 years old, do sometimes visit the exhibition, I chose not to include participants below the age of 5 because the exhibits are aimed at older children and because she considered it more important for younger children to focus on learning, rather than being disrupted by the research process.

The maximum sample size was set at 100 respondents. A quota sampling strategy was used to ensure a minimum level of participation within each group. According to the research by Blaikie and Priest (2017), quota sampling represents a minimum set target of sample group or respondent that is required for research, following which, the study will stop collecting the data. Therefore, a minimum of 25 participants for each group was targeted (representing children, teenagers, adults, and elder adults). However, since the target sample might be overly ambitious, I initially aimed for 16 participants. Upon completion of the study, I was able to attain 23 families that participated in the study. Participants were selected in family groups, which was appropriate for both investigating whole-family learning and ensuring that younger participants had appropriate supervision for participation so that consent could be given. This sampling strategy meant that more than 25 families in total were selected, with differences in family size and composition. The quota selection involved choosing the most interactive group of families that were immersed in the makerspace activities, which contributed to effective data collection practice from the observation.

To recruit the sample, I selected families at random on observation days. The adult(s) in charge of the group were approached and asked to participate in the study. If the adult(s) agreed to participate, I explained the data collection process and provided an information sheet. Informed consent sheets were then completed, and demographic information was taken for all family members. The process of data collection, including the questionnaires, observations, and interviews, was then completed as explained below.

3.7 Research Instruments and Method of Data Collection

The research included a combination of quantitative surveys, qualitative in- depth interviews, and qualitative observations to get insights into the experiences and learning processes of family visitors at NSM Enjoy Makerspace. In this study, questionnaires were used to produce the quantitative data, whereas observations and interviews were used to generate the qualitative data. The purpose of the questionnaire was to examine the experiences of visitors who engage in learning as makers, as well as assess the many aspects that contribute to their engagement and the learning outcomes, they achieve via their participation in Enjoy Maker Space programmes. The observations explained how visitors of all ages learn as a maker, their engagement outcome, motivation, skills, and their character when participating in the activities, whereas semi- structured interviews were used to explore visitors opinions about their motivation, learning, skills, inspiration, and creativity after participating with the Enjoy Maker Space activities. The method of study in this research was separated into five tools grouped into three stages of data collecting as shown in the following figure.

Stage 1- Pre-participating Enjoy Maker Space

- Engagement Observation (EO)

Stage 2- While participating Enjoy Maker Space

- Engagement Observation (EO)

- Skill Observation (SO)
- Motivation Observation (MO)

Stage 3- Post participating Enjoy Maker Space (EMS)

- Enjoy Maker Space Learning Outcomes Questionnaire (EMSLOQ)
- Enjoy Maker Space Motivation and Learning Outcomes Interview (EMSLOI)

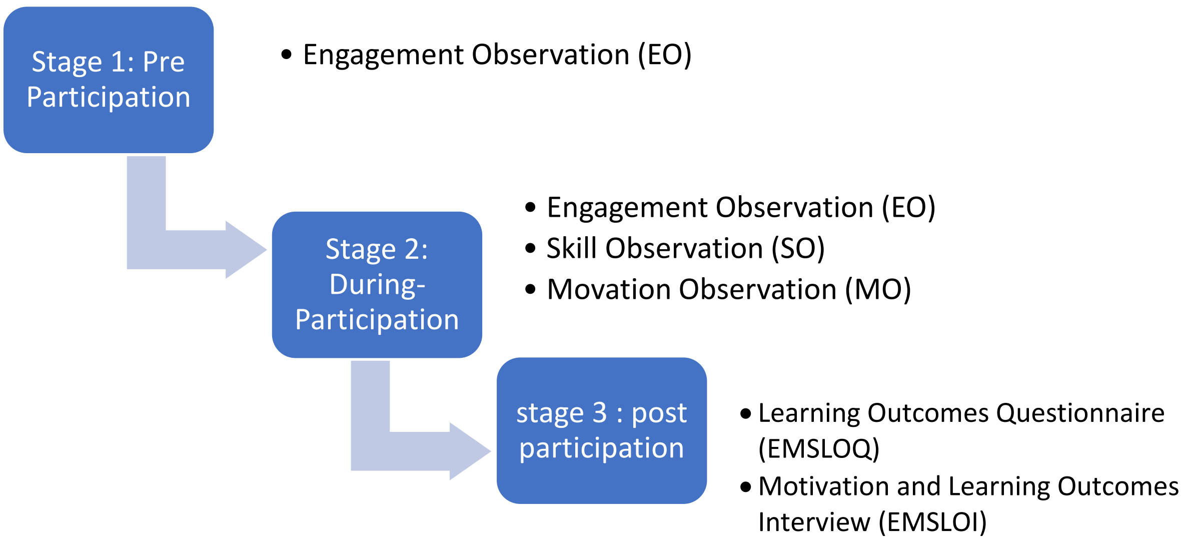

Figure 11: Overview of stage of the Data Collection Process

3.7.1 Observations

The first stage of the data collection process was observation. Observations are a common technique for data collection in both educational research and research in museums and exhibits (Creswell and Guetterman, 2020; Hohenstein and Moussouri, 2017). In both fields, observations offer an opportunity to investigate how individuals engage with materials or exhibits and how the actual process of learning takes place. This research used participant observation to observe all ages of visitors learning from Enjoy Maker Space a science museum. Observation allows a researcher to gain live data on physical settings (environment and resources), human settings (characteristics of visitors), and interaction settings (engagement) and programme settings (Morrison, 1930). In the context of this study, the observation approach as a methodology is performed within the domain of Enjoy Maker Space at a science museum, also referred to as a programme setting - allowing the study of characteristics of visitors, engagement, environment, and resources. Moreover, participant observation is suitable for a small group, brief time events and activities that can be assessable to observe. Enjoy Maker Space is a maker activity that allows small groups to learn the tools and the process of making things in one hour. In the observation methodology, I have used 1 explainer, 4 assistants and the researcher herself to be participant observers. These observers will observe participants during the Enjoy Maker Space in many aspects to follow code, category, and subcategory of observation – as presented in the following table section of 3.7. Each of the categories and sub-categories of observation are clarified with each of the codes.

Using participant observation, I was capable of acquiring data on how visitors tend to learn from Enjoy Maker Space activity, factors that encourage visitor learning, visitors motivation, knowledge, skills, inspiration and creativity and visitors learning outcomes as a maker through Enjoy Maker Space. The observers are inclined and instructed to keep a keen note of visitors character, behaviour, engagement, motivation, skills, and creativity by taking notes of codes, categories, and sub-categories. This research employs three participant observations to obtain descriptive data of all age visitors learning with EMS, through Engagement Observation (EO) and Skill Observation (SO).

This study used three observation instruments (shown in Appendices I, II, and III). The Engagement Observation (EO), is adapted from a prior toy engagement instrument (Kanhadilok and Watts, 2013). The EO investigated five aspects of engagement, including 1) engagement with the activity, 2) learning from the activity, 3) group involvement, 4) engagement with the environment and resources, and 5) expression and conversation. The Motivation Observation (MO) was adapted from previous research in makerspaces (Vongkulluksn et al., 2018). This included three aspects of motivation, including 1) situational interest, 2) achievement emotions and 3) self-efficacy. The Skill Observation (SO) was adapted from two sources (Hooper-Greenhill, 2007; Partnership for 21st Century Learning, 2015). This observation includes three domains, 1) learning skills, 2) literacy skills, and 3) career and life skills.

Observations were completed during the participating family's visit to the NSM Enjoy Makerspace exhibit. To conduct the observations, the researcher (myself) and volunteer assistants remained in an inconspicuous location while the family was visiting the NSM Enjoy Makerspace exhibit. Each observer completed a single observation throughout the visit, using a paper form to record codes and observations.

3.7.1.1 Engagement Observation

The Engagement Observation (EO) in this research was adapted from engagement observation with traditional Thai toys activity as recommended and previously adopted in the study by Kanhadilok (2013) and divided into five engagement codes: 1) engagement with the activity, 2) learning from the activity, 3) involve in their group, 4) engagement with environment and resources and 5) expression and conversation. Codes and categories of this observation are illustrated in Table 7 below:

Code	**Category**	**Sub-category**
EA1.0	Engagement with the activity	
EA1.1		• Explores the goals and ideas of the activity
EA1.2		• Observes the activity strongly and is involved
EA1.3		• Succeeds in the goals of the activity
LA1.0	Learning from the activity	
LA1.1		• Follows the activity
LA1.2		• Asks Questions
LA1.3		• Answers the questions
LA1.4		• Practice skills
I1.0	Involvement in their group	
I1.1		• Shares the materials or tools with others

Code	Category	Sub-category
I1.2		• Help others to do a task
I1.3		• Practice the task with others
I1.4		• Talks or discusses with others
EE1.0	Engagement with the environment and resources	
EE1.1		• Explores environment and resources
EE1.2		• Learn the material and learn how to use equipment.
EE1.3		• Cooperate with the Explainer and Assistants
EE1.4		• Interested in the Maker Space handbook
EC1.0	Expression and conversation	
EC1.1		• (Verbal/ explain, asks questions, answer questions, expresses like/dislike, conversation, etc.) Present in the conversation form.

Table 11: Codes, categories, and sub-categories of Engagement Observation
(Source: Adapted from Kanhadilok (2013))

3.7.1.2 Skill Observation (SO)

The Skill Observation (SO) in this research was adapted from the partnership for 21st Century skills (2008) and Generic Learning Outcomes (GLO) of the Research Centre of Museum and Gallery (Hooper-Greenhill, 2007), from which the observational categories and measures were adopted. This observation is used to observe the skills of visitors when participating with EMS at a science museum. The main topic of maker skills is separated into 3 types: 1) learning skills, 2) literacy skills and 3) career and life skills. All codes, categories and sub-categories will be presented in Table 8 below. These categories do not include behavioural changes for participants who are unaware of observation, because the research protocol required me to approach the families before commencing observation.

Code	Category	Sub-category
LE1.0	**1. Learning Skills**	
LE1.1	1.1 Knowledge and skills	
LE1.2		• Understand how to use tools
LE1.3		• Understand the making process
PS2.0	1.2 Problem Solving	
PS2.1		• Find the problem of making the process
PS2.2		• Select a variety of ways to repair
PS2.3		• Repair the product of the project completely
CM3.0	1.3 Communication	
CM3.1		• Listen and participate with other people
CM3.2		• Discuss with other people during making process
CM3.3		• Describe the product of the project to other people
CO4.1	1.4 Collaboration	
CO4.2		• Share the material with others
CO4.3		• Help other people to do a task
CO4.4		• Collaborate with teamwork
CK5.0	1.5 Creativity Skill	
CK5.1		• Make a new product
CK5.2		• Find a new way to make the process

Table 12: Codes, categories, and sub-categories of Skill Observation - A

Code	Category	Sub-category
LC1.0	**2 Literacy Skills**	
LC1.1	2.1 Information Literacy	
LC1.2		• Search for more information from many media
LC1.3	2.2 Technology Literacy	
LC1.4		• Use computer and internet for EMS
LI1.1	**3 Life Skills**	
LI1.2	3.1 Flexibility and Adaptability	
LI1.3		• Adapt suitable tools and materials for making processes and product
LI1.4	3.2 Self-Direction	
LI1.5		• Plan to finish product and project
LI1.6	3.3 Social Skills	
LI1.7		• Share ideas with the group
LI1.8		• Teamwork
LI1.9	3.4 Productivity	
LI2.0		• Finish product of the project
LI2.1	3.5 Leadership	
LI2.2		• Lead the group to do the project

Table 13: Codes, categories, and sub-categories of Skill Observation - B

3.7.2 Questionnaires

The data gathering process moved to its second step by starting to distribute questionnaires. Questionnaires are commonly used to collect data and are considered standardised instruments. They are especially useful for gathering quantitative data

(Fowler, 2014). Brace (2018) states that the questionnaire can collect different types of data, such as open-ended and closed-ended formats from various categories. This feature makes it a useful tool for collecting data.

Enjoy Maker Space Learning Outcomes Questionnaire was adapted from Vogkulluksn, Matewos, Sinatra and Marsh (2018), Generic Learning Outcomes (GLO) of the Research Centre of Museum and Gallery (Hooper-Greenhill, 2007) and Toy Learning Outcomes (TLO) questionnaire (Kanhadilok, 2013). These sources were chosen because they have been used in similar learning contexts and have already been shown to be effective in Thai learning contexts, This measure was adopted because it had been used in similar learning contexts, this measure was chosen because it had been used in similar learning situations. We adopted this measure because it worked well in similar educational settings. This study also utilizes and explores the use of an objective methodological design, focusing on collecting demographic responses from the respondents. The demographic responses comprise of information associated with gender, age, and educational background of the respondents. The demographic information allows portraying an understanding of the characteristics of different participants that were involved in this study.

The final NSM Enjoy Makerspace Learning Outcomes Questionnaire (EMSLOQ) is attached in the Appendix. The questionnaire collects data in three parts, using a combination of open-ended and closed-ended items. Part 1 collects general information, including demographic and educational information, using standard categorical demographic items.

Part 2 collects data regarding the interest in the learning environment and the learning experience overall. There were four different sources for items in the questionnaire. The Family Learning and STEM Learning items were adapted from the Family Learning Questionnaire developed for visitor evaluation at the London Transport Museum (Francis et al., 2019). This measure was adopted because it had been used in similar learning contexts. However, I translated and simplified the language of the questionnaire to adapt it to the audience. Furthermore, researchers such as Bell (2007) stated that questionnaires are an effective means of communicating with children, who could often have short attention spans. Experiential learning was assessed using items developed by me, focusing on intellectual, practical, and problem-solving and communication skills. The Immersion assessment tool was derived from a questionnaire that was originally created to evaluate the level of immersion experienced in video games (Jennett et al., 2008). The assessment of Flow Experience was conducted through the utilisation of the Flow State Questionnaire (FSQ), as outlined in the study conducted by Magyaródi et al. In 2013. The identification and acquisition of these two constructs proved to be particularly challenging due to their lack of prior investigation within the realms of makerspaces and museums. Consequently, the utilisation of source scales was deemed necessary in order to establish a broad correspondence with the notions of flow and immersion, while still permitting adjustments to suit the specific research context.

The questionnaire was Initially presented in Thai language for ease of understanding and later converted into English language using back-translation, as recommended by Tyupa (2011) to check the translation from English instruments and ensure translation quality. To collect questionnaire data, each participant was given a paper questionnaire pre-numbered with their family identification number. They then completed the questionnaire with assistance if necessary.

3.7.3 Interview: Motivation, Inspiration, Creativity and Learning Outcomes Interview (MLOI)

Semi-structured interviews were used to collect qualitative data from families following their experiences. Semi-structured interviews are ideal for collecting qualitative data in a relatively short period because they balance the focus of structured interviews and the opportunity to provide more information and challenge the researcher that unstructured interviews offer (Galletta, 2013). This characteristic of semi-structured interviews was important for the research because I did not want to take up much time from the participants, whose primary intention for their visit was to enjoy the learning experience of the museum. The interview guide, attached in Appendix 6, was completed following the pilot test of the research instrument. The interview questions are open-ended questions intended to investigate the experience of the interview from multiple perspectives and permit information sharing. The use of an open-ended instrument allowed the parents to convey rich information that could be useful for interpretation. The items, below, are based on the perception of the participants, rather than on the researcher's assessment or a formal assessment. For example, interviewees were prompted to reflect on whether they had engaged in family learning what they gained from it, and whether they had gained STEM knowledge from the activity. Differences in perceived learning between parents and children could also be investigated through these reflective statements. These self-reflective statements were used as the basis for assessment through the analysis process.

To collect interview data, the family participants were asked to enter an interview room as it would allow recording without noise and ease of transcription of the data. The family adult(s) were asked once again to consent to recording for themselves and their children. I then asked the interview questions and responses were recorded. The semi-structured interviews were collected through audio-recordings available through the devices, and the audio-recording is transcribed to interpret in this study. These responses were then transcribed for analysis.

Code	**Category**	**Sub-category**
MO1.0	Motivation	
MO1.1		• Participants situation Interest
MO1.2		• Participants achievement emotion
MO1.3		• Participants confident
IN2.0	Inspiration	
IN2.1		• Inspire to learn more about maker's knowledge and skills
IN2.2		• Inspiration about developing new project after activity

IN2.3		• Inspiration about developing innovation projects in the future
CR3.0	Creativity	
CR3.1		• Develop creativity skills from EMS
CR3.2		• Creativity for new idea to make product and project lead to development innovation
LO4.0	Learning Outcome	
LO4.1		• Gain family learning
LO4.2		• Gain STEM learning
LO4.3		• More skills development from EMS

Table 14: Codes, categories and sub-categories of Motivation and Learning Outcomes

3.8 Data Collection Process

Data collection in this research started with a pilot study and then continued with the main study. The purpose of the pilot study was to test the methodology of the main study on a small scale and identify any issues that could occur during the process. I plan to conduct the pilot study in January 2021 and the main study in June 2021. The study used a mixed-methods research methodology to assess and discern variations in educational achievements between parents and children within makerspaces and science museum education. First, one of the key process of data collection includes an observation-based data collection strategy. In the context of this study, the researcher focuses on collecting observation-based data involving the participants engaging in reviewing the participants' ongoing behaviour in a natural environment (Fix et al., 2022). In the context of this report, the natural environment comprises the makerspace environment, whereby the researchers observe participants ongoing behaviour, exposed to different subjects of study. In the context of this research, the behaviour of the parent and children were explored, specifically when undertaking the makerspace activity, and this can allow for enhancing the learning experience of the researchers. In addition to that, the researcher's participation also comprises of understanding subjective experiences of each subject.

Similarly, I have undertaken observations of parent-child dyads engaging in makerspace activities. Please observe the participant's interactions, levels of engagement, and the degree to which they have actively participated in the learning process. This has yielded qualitative insights into the processes of learning. Semi-structured interviews were done with parents and children in different sessions, which focuses in using the qualitative open-ended questionnaire. As referred to in figure 11 of this study, the researcher has also applied motivation observation. Motivation observation learning emphasizes the study of imitating behaviour and is primarily based on learning practice through others. Questions in the qualitative interview included examples such as – "Please provide me with an overview of your learning objectives, past experiences, and the knowledge and skills you have acquired via your involvement in makerspace activities". Qualitative data analysis methods, such as thematic coding, have been implemented to discern reoccurring themes within interview replies, observations, and open-ended survey questions that pertain to discrepancies in learning.

Before conducting the pilot study, I prepared all tools of the study: questionnaire, observation schedule and interview questions - ensuring that there were no challenges when the data collection phase began. Then I connected with the Enjoy Maker Space staff for the date and details of both studies, ensuring that all forms of permissions were acquired and therefore, the scheduled dates were in tandem with the Maker Space activities. Furthermore, I ensured that when conducting the pilot study in the area site, a meeting was hosted that allowed me to explain all details of the pilot study (such as the instrument of research, activities programme and qualification of visitors that the programme needs) to the explainer, the assistants, and the other staff of NSM that are involved in the programme.

After the pilot study, I did a post-pilot study meeting with the staff again for feedback on the pilot conducting data and the results of observations and the interview. The information gained, which was mostly surrounding the situation of the study and avoiding disruption of visitor flow, was incorporated into the design of the main study. Similarly, I conducted a reliability and validity of the research instruments. This was done to ensure the study's methodological rigour, ensuring that, the questionnaires were designed and intended to achieve the objectives of this project.

The comments from the staff of NSM and the data from the questionnaires, observations and interviews were considered for improving all tools and the processing of collecting data for the main study. The main study took place in June 2021. Following that, the actualised study was conducted, with the idealised number of participants, and the data was recorded securely in a password-protected drive. Following the completion of the analysis and this study, the data will be erased as a means of protecting the privacy of the respondents.

3.9 Data Analysis Procedure

The quantitative analysis began with descriptive statistics for all variables. The descriptive statistics were used to build demographic profiles and investigate interest and overall learning in the NSM Enjoy Makerspace exhibit. Quantitative analysis of the data collected from questionnaires was originally planned to be conducted using a structural equation modelling (SEM) approach. SEM-based approaches are appropriate for complex research models with relationships between multiple latent variables (Byrne, 2016).

However, due to the complexity of applying the SEM approach and confirmatory factor analysis, I opted for a simpler approach of using descriptive statistics, considering the questionnaires developed were simple and straightforward, and many of them were also collected from children (Holcomb, 2017). (The sample details will be further explained in detail in this chapter). Therefore, via the use of such descriptive, the scholar was able to organise the data into an understandable format and use graphical techniques to represent these summaries for a better understanding of the data distribution. These techniques include histograms, pie charts, bar charts, and others. Moreover, Canva was also used to further modify the charts to be more comprehensible to a diverse audience, giving it a more interactive approach. Specifically, for demographic profiles, descriptive statistics enabled me to summarise personal characteristics such as age, education level, profession, and other demographic information of the participants. These demographic details were an important aspect of the data collection, as they gave a brief yet specific background of the sample and allowed me to develop insights into the type of visitors that are attracted to the NSM Enjoy Makerspace activities. In addition to that, for further insights, the scholar has adopted the use of a correlation analysis, to identify the relationship that co-exists between different learning factors among the children and the parents. The use of correlation analysis (Warne, 2021) allowed me to discover the learning experiences of the sample, along with how interested they were in the NSM Enjoy Makerspace activities. Using the correlation analysis - the measure of Pearson's "r" was utilised, aiming to identify whether 2 or more learning factors such as experiential learning, immersion, experience, STEM factors, and facilitation were correlated with each other or not. In performing Pearson's "r", the hypothesis $r=0$ indicated that there was no relationship between the variables, and $r\neq0$ represented that, there was a relationship between the variables. The correlation analysis has been performed in the context of the parents, and the children, which can allow an understanding of the differences in the factors that influence the learning experience among the parents and the children. Moreover, using Pearson's correlation also helped in identifying which parts were most enjoyed by the participants. These elements then were further utilised in the triangulation of the findings with the qualitative data also collected.

However, it is notable that my analysis at this stage was simple, avoiding any complex statistical measures, as the goal was to keep the analysis easy to interpret and to ensure that it was simple enough to be integrated with the qualitative data that were collected from interviews, observations, and other methods. By doing so, I ensured that the overall findings of the research remained consistent and comprehensive across multiple data collection techniques. The descriptive statistics served as a substance, building a story that would be further enriched and validated by the more detailed and deeper data set collected from the qualitative methods.

Next is the qualitative analysis. The purpose of the qualitative analysis used for the observations and interviews was to explain the participant's view on the NSM Enjoy Makerspace experience and how it contributed to learning. A qualitative content analysis

(QCA) approach was used for the text-based data and information (Krippendorff, 2018). While quantitative methods for statistical and numerical analysis that is focused on techniques like frequency counting and observing adjacency, in QCA the emphasis is more on interpreting the data and its meaning (Mayring, 2000). A directed approach was used here, with the initial coding frame derived from the literature review (Hsieh and Shannon, 2005). The coding frame was then refined through application to the textual data until it reached theoretical saturation (Krippendorff, 2018). Following this, the coding frame was refined and then re-applied to the remaining texts. After all interview transcripts and observations were coded, I identified key themes and created narrative descriptions for each of the themes. Furthermore, the role of different individuals, including the 1 explainer, 4 assistants and the researcher herself as participant observers is further reviewed as follows.

- Explainer- The explainer's role in this NSM makerspace activity was associated with demonstrating and showcasing the syringe rocket activity. During the Makerspace activity of the NSM her function was to lead the other participants through the syringe rocket activity, which includes telling them how to do it, providing the steps and techniques, and making sure that they have a clear understanding of the process. Furthermore, the explainer also facilitated expert learning, to ensure engagement in terms of building the learning atmosphere and making it participative and sociable. In addition to that, there was need for training participants in safety guidelines, ensuring that the makerspace is being properly monitored to prevent accidents, and addressing any safety issues that may arise during the activity.
- Assistants- All assistants occupy an indispensable position that helps them to align themselves with the participants in the context of the syringe rocket activity. They aid the parents and children with their questions, clarifications and problem-solving any difficulty that may come to them during the activity. In addition to that, the assistants, worked alongside participants, support group-based learning, while facilitating group interactions, fostering teamwork, and building a cooperative learning environment among the family groups.
- Researcher- The researcher in this case has several tasks, including being participant observer, data collection, coordination, and analysis and reporting. Herein, the role

begins with documentation of participants' experiences, and ensuring an inside view on the learning dynamics of the family unit learning. Similarly, the researcher, being responsible for data collection using different methods such as observations, interviews, and surveys, is important part of this task, superivisng all stages of the multi-disciplinary approach to ensure that each data gathering step is done well. Finally, the researcher also invests time in analysing and reviewing events and data, by undergoing thematic and quantitative analysis, and attempting to derive meanings from findings to address the research questions.

This was then integrated with the findings from the quantitative research using triangulation to answer the relevant research questions.

This study therefore has utilised both quantitative and qualitative for collecting data, and resultantly, the strategy of each method for collecting and analysing data is described with the question of the study as presented in Table 11 below.

Research question	**Data collecting**	**Data analysis**
1. What factors encourage family visitors experiential learning outcomes that can be achieved through NSM Enjoy Makerspace activities at the National Science Museum, Thailand?	**Descriptive Quantitative data** - Enjoy the Maker Space learning outcome Questionnaire	- Descriptive Statistics analysis - Content analysis
	Descriptive Qualitative data - Motivation and Learning Outcome Interview	- Content analysis
	Interpretative Qualitative data - Engagement observation - Motivation observation - Skill observation - Photographic evidence	- Numerical analysis - Documentary analysis - Photographic analysis

Research question	Data collecting	Data analysis
2. What arrangements for experiential learning within the NSM Enjoy Makerspace affect the relationship between engagement, environment, resources and outcomes?	**Descriptive Quantitative data** - Enjoy the Maker Space learning outcome Questionnaire	- Numerical analysis - Content analysis
3. What learning outcome can be identified because of the NSM Enjoy Makerspace activity regarding developing twenty-first-century skills?	**Descriptive Quantitative data** - Enjoy the Maker Space learning outcome Questionnaire	- Numerical analysis – Correlation Analysis - Content analysis
	Descriptive Qualitative data - Motivation and Learning outcome interview	Content analysis
	Interpretative Qualitative data - Engagement observation - Motivation observation - Skill observation - Photographic evidence	- documentary analysis - Photographic analysis

Table 15: Method of collecting data and data analysis.

3.9.1 Interpretative Analysis

The objective of both thematic and content analysis was to scrutinise materials from life narratives in a manner that was both descriptive and enlightening. This was accomplished by the deconstruction of the text into petite units and subsequent submission to treatment. Content analysis was also particularly conducive to the study of the multifarious aspects of education. As per Saunders et al., (2019), thematic analysis was a valuable and adaptable research instrument that could yield an in-depth analysis of the data. It involved pinpointing common strands that pervaded a complete set of interviews. Furthermore, both qualitative and thematic analysis permitted the examination of data in an array of manners. Therefore, the content analysis was a process that empowered the scholar to examine and quantify data simultaneously. It employed a descriptive approach to interpret the data and its quantitative counts. On the contrary, thematic analysis was a more complete and distinctive dissection of the data.

3.9.2 Multi-Method Analysis

The exploration of the NSM Enjoy Makersapce activity is measured to review the existing research gap, that is related with family involvement and experiential learning. The primary analysis method used in this study is structured around the multi-method approach, which combines a range of instruments, which includes (i) observation, (ii) interview, (iii) close-ended survey, (iv) photographic observation, and others. The use of multi-method analysis reviews and identifies as a significant practice in ensuring active learning, co-operative learning, and family involvement practices. The advantage of multi-method analysis is that a research study is capable of employing multiple data collection approach and analysis strategies, that allows addressing the key issues through perspectives such as, qualitative approach including observation and interview, quantitative method such as survey One of the key approaches in the multi-method approach was a data collection strategy, which includes pre-participation engagement observation, during- participation observation and sureys, and post- participation interviews and surveys. Using this combination of tools, the study adopted the use of anapproach holistic understanding of developing a comprehensive analysis in defining the relationship between family dynamics and makerspace learning. Comparing to different technologies, the study employs the uses the EMSLOQ survey and photographic analysis and is further complemented with Bricolage and photographic collage analysis. Bricolage was used for converging multiple findings from primary and secondary research study together. Each of tools of data employed in this study is further analysed and discussed and presented using a Bricolage analysis.

3.9.3 Bricolage and Collage

McSweeney and Faust (2019), in their recent study, have indicated that Bricolage, as a research methodology, encompassed the integration of a multitude of data-gathering techniques and sources. Although, I found it quite vague in the description, but somewhat concluded that bricolage at the end of the day, was a collaboration of different methods, which the scholar believed to be an alternative term to multi-method. As indicated further in McSweeney and Faust (2019), bricolage produced an interpretation of the research subject that was both comprehensive and delicately layered. This methodology was marked by its openness to a diversity of perspectives, means of comprehension, and interdisciplinary frameworks. This suggests that there is an aspect of creativity to the practice of bricolage, which is not necessarily implied in the use of multi-method research.

Furthermore, bricolage could include practices of transdisciplinary aspects, along with mixed-method processes as noted by Klein et al., (2001), which then further enforced the scholar's understanding of bricolage as a methodological approach that integrated a combined approach of multi-methods. Khein et al., (2001) have indicated that transdisciplinary research involves the collaboration of individuals from a spectrum of fields to disentangle multifaceted problems that could not be addressed by a single discipline. Therefore, it is believed that by combining diverse perspectives, transdisciplinary research could produce innovative and effective resolutions to intricate challenges (Klein et al., 2001). In this context, Denzin and Lincoln (1994) indicated that although bricolage entails multi-textual communication, referring to the use of an assortment of data forms and communication techniques to disseminate research findings, these could also include written texts, visual representations, and other modes of multimedia. Resultantly, by harnessing multiple forms of communication, I was able to reach a more expansive audience and convey their findings in a more engaging and accessible manner. Therefore, bricolage served as a flexible and adaptive approach to research, capable of incorporating various methods, practices, and forms of communication, to produce a comprehensive and nuanced understanding of the research topic.

Moreover, Denzin & Lincoln (1994) explained the significance of methodological bricolage in enhancing adaptability and reflexivity. The term "bricolage" refers to an individual who employs the tools available to them to accomplish a given task. Bricolage involves the merging of multiple perspectives and practices to augment the rigour, breadth, complexity, richness, and depth of an investigation. By commissioning accessible methods and materials that are empirical, I could introduce new strategies as the research unfolded, or in this case, in response to shifts in the context such as a pandemic. Therefore, this approach enables mixed methods researchers to adjust their data collection approaches to meet the demands of shifting research contexts as identified in the conclusive remarks of Denzin and Lincoln (1994).

Resultantly, the researcher-as-bricoleur is self-reflective and recognises that their work is influenced by themselves, the participants, and the setting (Denzin & Lincoln, 1994). Bricoleurs can adopt various perspectives, such as interpretive, narrative, theoretical, political, and methodological and centre their discussion on methodological bricolage. This research approach "seeks to be open to multiple perspectives, ways of knowing, power relations, and strives to adopt an interdisciplinary framework" (McSweeney & Faust, 2019, p. 343). Unlike methodological templates, which are reactive approaches to research, bricolage is proactive and requires contemplation on how to engage with the methods (McSweeney & Faust, 2019).

In the study of visitor learning and behaviour change in protected areas, a methodological bricolage approach was implemented to adapt to the challenges posed by the COVID-19 pandemic, while ensuring rigorous and high-quality data for analysis. Bricolage was particularly useful in this research because there was a large number of data sources, which were not always commensurate with each other (for example observations versus interviews versus questionnaires). The bricolage approach enabled me to creatively integrate data from these very different sources to provide a multi-vocal perspective on family learning within the makerspace. In undertaking this technique in this study, I individually analysed each of the data-collecting instrument findings, and the conclusion of each tool collaborated via the bricolage technique. This allowed me to integrate 4 or more data-collecting instruments into a conclusive finding. Using a bricolage approach is followed through after doing the thematic analysis and generating preliminary findings, which provides a groundwork for the procedures of analysis, and ensuring consistency in the findings of the research.

3.10 Pilot Study

3.10.1 Overview of the Pilot Study

The purpose of the pilot study is to trial and refine the procedures that will be undertaken in the main study. Therefore, the pilot study was conducted, broadly speaking, in the same way as the main study. Initially, I had planned to conduct the pilot study in November 2021, but due to the COVID-19 pandemic, this took place in August 2022. After obtaining approval from the Brunel University ethics committee, I contacted the NSM Enjoy Makerspace staff (the educators, assistants, and other relevant staff at the NSM), to organise a meeting. At that meeting, I informed them of the proposed dates and details of the pilot study. I explained the details of the pilot study such as the assessment tools used, the activities to be undertaken in the NSM Enjoy Makerspace, the number of visitors that the study requires, and the protocols of the pilot study to the educators, the assistants, and the other staff of the NSM that involved in the study. However, there are two key differences between the pilot study and the main study. Firstly, the sample for the pilot study involves four pre-selected families who visit the museum. Secondly, respondents in the pilot study were asked to offer feedback at all points of the research, beginning with the observations. This process allowed me to refine the recruitment process, the data observation techniques, and the assessment tools, and to practice their observations, following feedback from respondents. The pilot study used a sample of 4 families who visited the NSM Enjoy Makerspace, at the National Science Museum, in Thailand. The sample was separated into four groups: 1) children aged 10 - 12 years, 2) teenagers aged 13 - 20 years, 3) adults aged 21 - 60 years and 4) elders aged 61 years and over. Families were approached for participation, and relevant consent was gained from the respondents, and observations, questionnaires and interviews were undertaken.

3.10.2 Reliability & Validity of the Study

In terms of the reliability test, this was conducted under the pilot study, which involved testing and studying using test-retest reliability. Test-retest reliability is defined as the process of repeated measurements of data in 2 separate occasions, which was applied in this study by collecting pilot data first followed by the actual data. A comparison between the pilot data and the actual data was performed to review the comparative differences between the 2 The advantages of using the reliability were based on the development of (i) stability analysis, (ii) practicality, and (iii) objective evaluation. First, using a test-retest reliability was a straightforward and easy methodology to apply when ensuring that the data gave consistent results over time. Using this methodological approach also requires minimal resources, and the participants were given same instrument twice. Therfore, no forms of complex softwares or change in the research instrument was required in performing the reliability analysis. Finally, the researcher also realized that the use of test-retest reliability allowed an objective comparison between the pilot study and the actual test eata. Focusing on the use of test-retest reliability analysis, the findings of this study were consistent with minor differences between pilot and actual test results. Hence, no forms of changes were made to the rsearch instrument. Seecondly, in terms of the validity aspect, the validity was acquired through a face validity approach. A face validity approach is the process of gaining subjective affirmation on the degree to which a specific instrument/tool can review or explaining the content/statement can explain a specific variable. Herein, the face validity was acquired by selecting a panel of individuals, such as, from the makerspace, and ensure that the findings acquired were relevant. The advanags of using a face validiy approach was, (i) quick assessmen, (ii) participant cooperation, and (iii) ease of communication. In line with the face validity findings, it was noted that, face validity was quick assessment process to ensure that the selected questions and statements measured what was intended to be measured. Participant and experts from the makerspace were used to make this judgement and analysis, and it was found that, majority of the participants agreed that the statements were clear and had clarity in defining the main variable.

3.11 Ethical Consideration

The research was designed to follow all ethical requirements of Brunel University's Code of Research Ethics. Ethical approval was sought using the appropriate procedures before commencing research. Evidence for approval is attached in Appendix 7. There were some features of the research which required special consideration because of their ethical implications. The biggest concern was the participation of children in research. Educational research and museum research both often involve children due to the research being about children and their learning needs (Creswell and Guetterman, 2020; Hohenstein and Moussouri, 2017). However, children still need to be protected because they are a vulnerable population (Wiles, 2013). This research ensured that no children or teens were included without consent from responsible adults (parents or grandparents), by only approaching adults in family groups and gaining permission from them to participate. Participants were also asked to reconfirm consent at multiple stages to ensure that respondents were aware of the research process and what it entailed. Families were not included if all members did not consent. This did raise ethical questions about familial pressure and power, as parents could attempt to force their children to consent. However, in practice, this was not seen to occur.

An additional concern was that of confidentiality. To protect confidentiality while allowing family surveys and interviews to be associated, each family was assigned a group number on all forms. Adults were also provided with the group number to allow them to withdraw from the study after participation. This ensured that if participants did change their minds, they could withdraw without breaking confidentiality. I did collect contact information from adults for accountability purposes, but this information was stored separately to avoid infringing on the confidentiality of participants.

3.12 Limitations of The Study

This research aims to study the perception of visitors of all ages learning with Enjoy Maker Space activity in the Science Museum at the National Science Museum Thailand. This research will conduct the research within the region of the Enjoy Maker Space room, and only one site at the Science Museum. The sample of this study contains visitors distributed in four levels of ages comprising of approximately 100 participants, including children, teenagers, adults and elders, who voluntarily participated in the activity. Most participants of this sample live in the same province where the Science Museum is located (Pathumthani) and the nearby provinces (Bangkok, Saraburi, Ayutthaya, Nakorn Nayok). However, it is imperative to note that, being that the majority of the visitors were from the vicinity of Bangkok, they do not represent all people of Thai society. For example, people from Bangkok may have different family structures (smaller nuclear families), different educational experiences and motivations, and different incomes and other aspects of difference from those that live outside cities. Hence, this leads to a challenge to the generalisability of the data. Furthermore, this research focuses on learning outcomes that emphasise knowledge, skills, inspiration and creativity and the factors that encourage visitors of all ages to learn to Enjoy Maker Space activities in the Science Museum. The research does not focus directly on scientific learning from the curriculum but focuses on skills learning and achievement. Hence, there is the potential limitation of the research scope, and its capability to be classified and applied to scientific and cognitive aspects of learning and achievement. Moreover, since I have designed a multimethodological approach, there are certain inherent limitations to this. A multimethodological approach implies the use of both "quantitative" and "qualitative" approaches to answer the research question. Although the use of a multimethodological approach allows for reducing limitations of the mono- methodological approach, the use of the multimethod was extremely time-consuming. In a time-constrained setting, it is recommended that a mono-methodological approach is employed. Hence, in the future, multimethod is only recommended in a setting with no time constraint. Secondly, despite the study being executed using a multi-methodological approach, the population sample scope is limited to NSM Enjoy Makerspace visitor groups. However, the concept of makerspace and family-experiential learning could also be acquired from broader regions, which could establish this study to have a generalisable result. Hence, this study can be limited to reflect the behaviour of families in Bangkok, Thailand.

3.13 Conclusion

This chapter has provided a detailed outline of the methodology adopted for this research, focusing on the exploration of family visitors becoming makers in the NSM Enjoy Makerspace at the NSM, Thailand. The objectives of the study were outlined, guiding the overall methodological design. An abductive paradigm towards theory development was employed in the study, utilising an amalgamation of qualitative and quantitative methodologies within the sphere of a multi-method research design. Moreover, the sampling strategy ensured a wide-ranging representation of age demographics, contributing to a rich and comprehensive exploration of the phenomenon in question. Through observations, questionnaires, and interviews conducted in three participation stages (pre, during, and post) within the Makerspace activities, detailed and profound data relating to visitor engagement, acquired skills, motivational aspects, and learning outcomes were anticipated to be procured.

Additionally, the integration of both quantitative and qualitative analysis techniques, coupled with the innovative employment of bricolage as an interpretative tool, ensures the research exudes robustness and flexibility. This methodological bricolage promises to capture the intricate facets of visitor experiences in Makerspace, transcending the capabilities of conventional methodologies. Furthermore, the pilot study carried out with a sample of four families, served as an indispensable preliminary step in testing the validity and efficacy of the data collection tools and protocols, thereby confirming their appropriateness for the primary study. Predominantly, the research design and methodologies were judiciously chosen to address the research objectives, contributing profound insights into family learning experiences within the milieu of makerspaces, especially concerning the NSM Enjoy Makerspace.

Therefore, finally, it can be noted that the scholar has a fusion of an array of research methods employed in this study promising to yield rich and nuanced insights into family learning within the confines of the NSM Enjoy Makerspace. The research methodology also establishes a formidable foundation for future explorations in similar environments, thus contributing to the perpetual evolution of our comprehension of family learning within the realm of informal educational settings. The application of this methodology is presented in the next chapter where all the data are presented and discussed.

CHAPTER 4: FINDINGS, ANALYSIS, AND DISCUSSION

4.1 Introduction to the Chapter

Chapter 4 uncovers the results of the quantitative and qualitative data analysis results carried out during the Enjoy Makerspace program. The study collected data from both children and adults, focusing on comprehending their interests, motivations, and perceptions of learning outcomes concerning the various activities they participated in. I implemented multiple data collection tools such as the Enjoy Makerspace Learning Outcomes Questionnaire (EMSLOQ), Engagement Observation Schedule, and STEM Learning Behaviour Observation Model. This chapter is divided into sections that present the findings of each data analysis tool, providing valuable insights into the participants experiences and perspectives on the program. The chapter also examines the DIY activity that participants enjoyed the most and their opinions on the agenda. Finally, a multi-method analysis of bricolage is presented, which explores the creative problem-solving techniques employed by the participants during the program.

4.2 Quantitative Data Results

The quantitative data results analysis is divided into two sections based on demographic distinctions of children and adults participating in the Enjoy Makerspace Learning Outcomes Questionnaire as mentioned in data collection section of methodology, referred to as EMSLOQ. The first section will illustrate the findings of children, followed by the next section on adults.

4.2.1 Enjoy Makerspace Learning Outcomes Questionnaire (EMSLOQ): Children

4.2.1.1 Demographic Findings

Here the descriptive findings of the sample participating in the EMSLOQ questionnaire are provided, illustrating their age, sex, and education.

Age	Frequency	Percent
5 - 8 years	13	30.40
9 - 12 years	37	56.50

13 - 20 years	3	13.00
Total	**23**	**100.00**

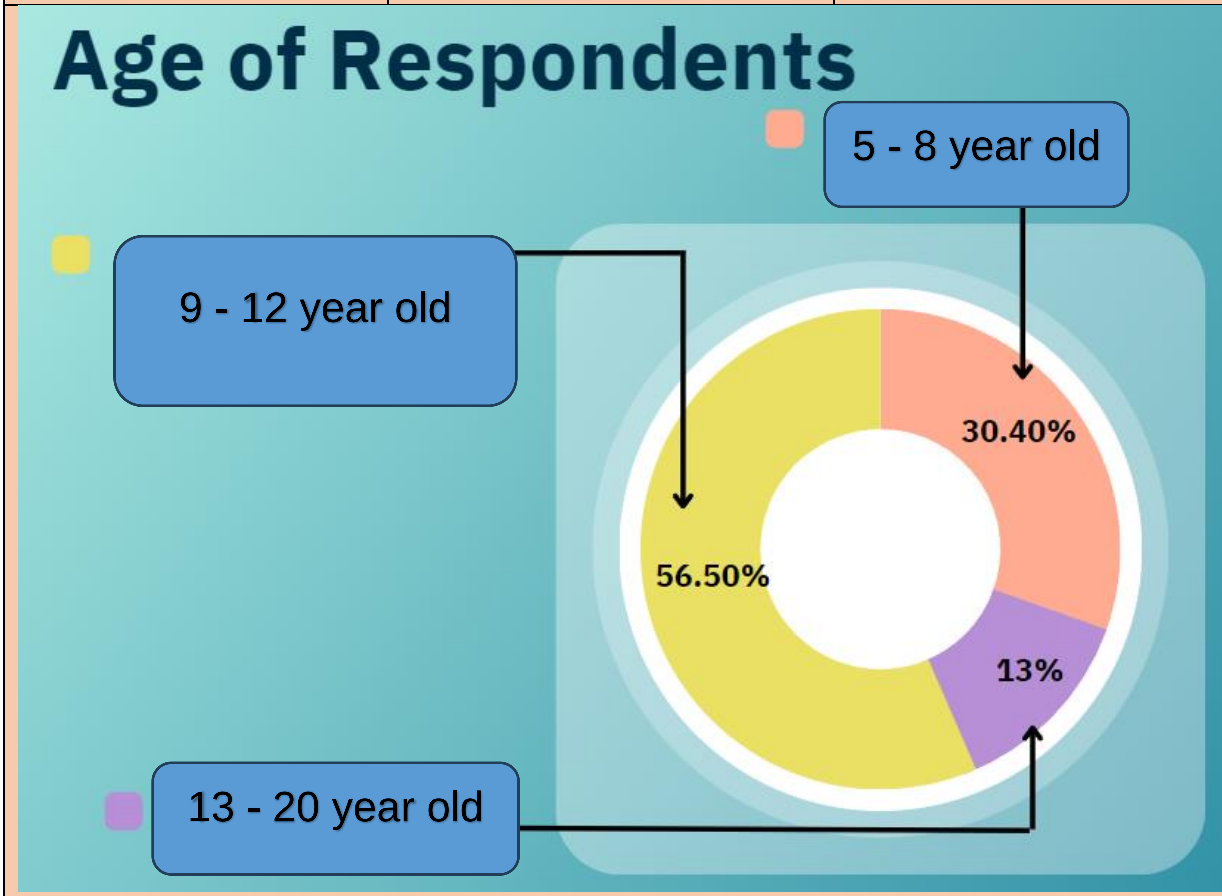

Table 16: Age of Participating Children

The table above represents the total number of respondents amongst children and their respective age brackets. The data was divided based on 3 categories, and those that were below the age of this respective brackets were considered under adult or older children supervision. The brackets that were considered were: 5 - 8 years, 9 - 12 years, and 13 - 20 years old. From the total of 23 participants, the majority (56.5%) fall into the 9 - 12 years category. The second majority was the age group is 5 - 8 years old, which accounted for 30.4% of the sample. The smallest percentage of respondents were those within the 13 - 20 years, which makes up only 13% of the sample. The initial and original age range was designed as an approximation of the intended data collection and inclusion criteria, with predominant target amongst younger, capable age brackets of children.

This could be due to the type of activity, which were primarily targeted to the younger age respondents and their parents.

Sex	Frequency	Percent
Male	14	60.90
Female	9	39.10
Total	**23**	**100.00**

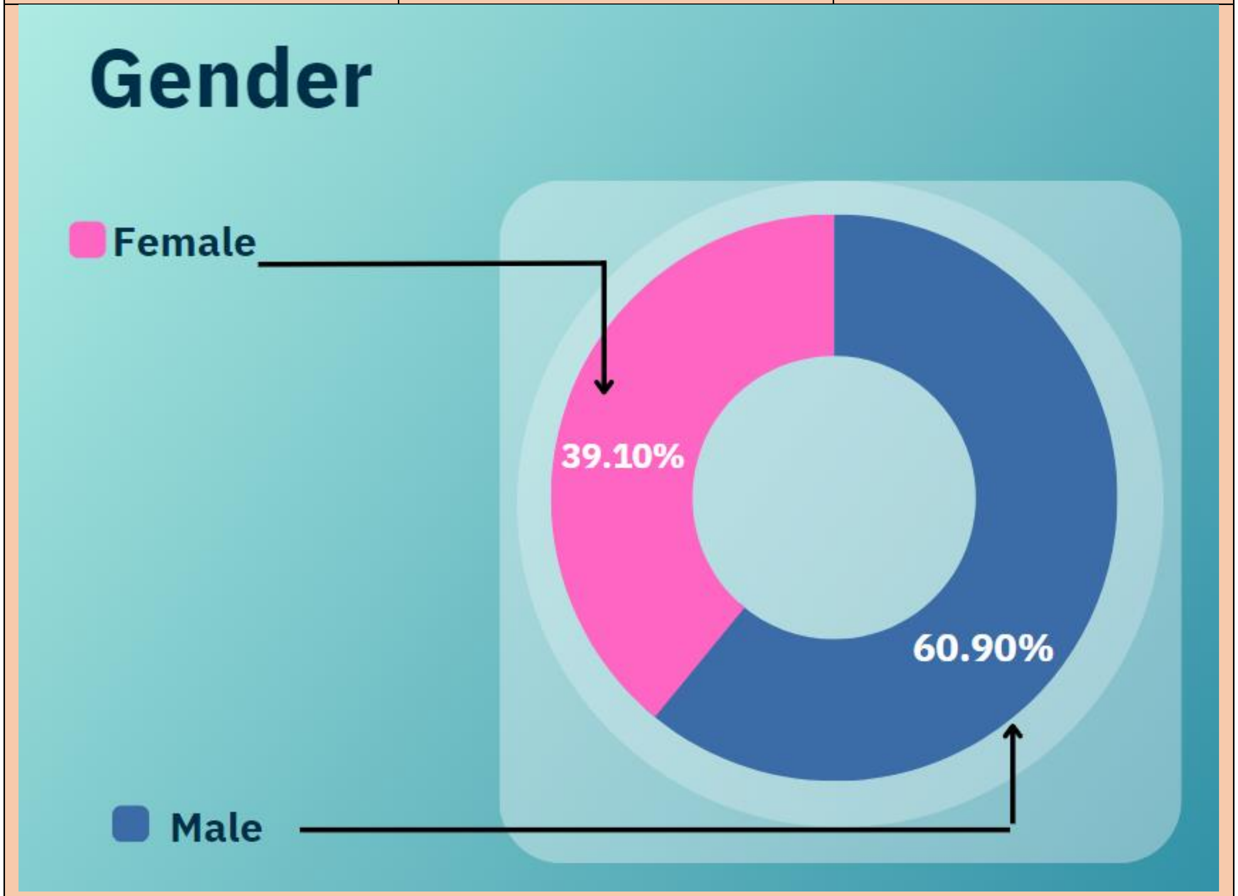

Table 17: Gender of Participating Children

Gender was the next demographic detail of focus. It was noted that the primary sample group accounted for male genders, accounting for up to 61%, while the second majority were females, accounting for up to 39%. This is slightly higher than the NSM's average child visitor rates, which, according to museum statistics are around 53% male. The statistics for the wider museum include many school visitor groups, which tend to be evenly split between genders. Thus, the larger number of boys in voluntary (non-school) visits to the NSM Enjoy Makerspace could be indicative of an early gender divide in interest in or access to STEM education. While this was not a specific issue investigated in this study, it is a possibility that should be considered since it affects the NSM's mission of STEM education.

Education	Frequency	Percent
Primary school	17	73.90
Secondary school	1	4.30
High school	3	13.00
Other	2	8.70
Total	**23**	**100.00**

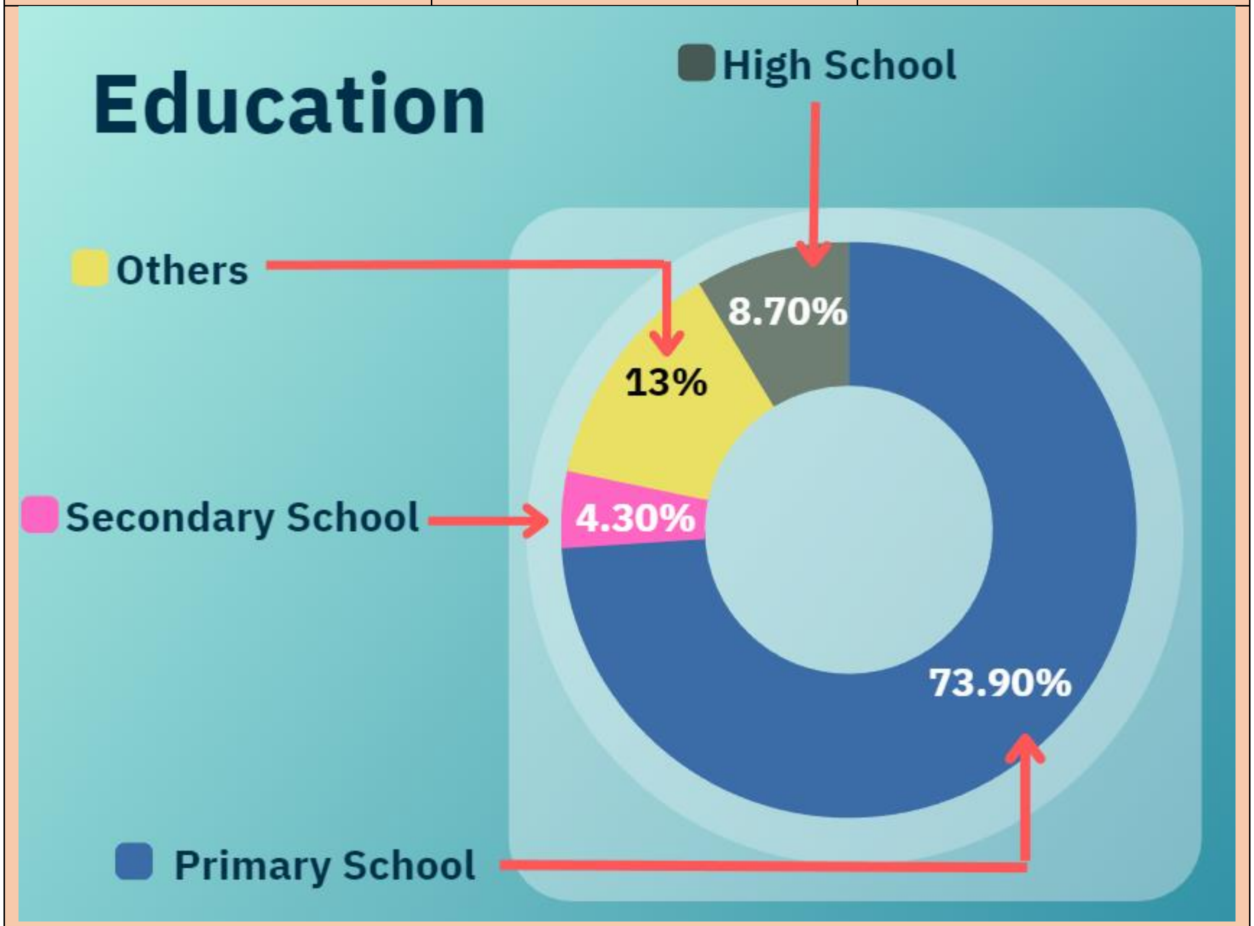

Table 18: Educational Background of Participating Children

The above table presents the educational background of the participating children in the Makerspace Programme. The findings presented by the study indicated that, a majority of the respondents were enrolled in *primary school* comprising of 73. 90%

(or approximately 17 children). Followed by that, 13% comprised of high-school students, 8.70% comprised of other schools (for example, not enrolled in any school or home schooling), and 4.30% comprised of secondary school.

4.2.1.2 Interest and Motivations towards Enjoy Makerspace

1) Do you take part in DIY (Do it yourself) activities on a daily basis?

Do you take part in DIY activities on a daily basis	Frequency	Percent
Often	9	34.80
Sometimes	6	26.10
Seldom	7	34.80
Never	1	4.30
Total	**23**	**100.00**

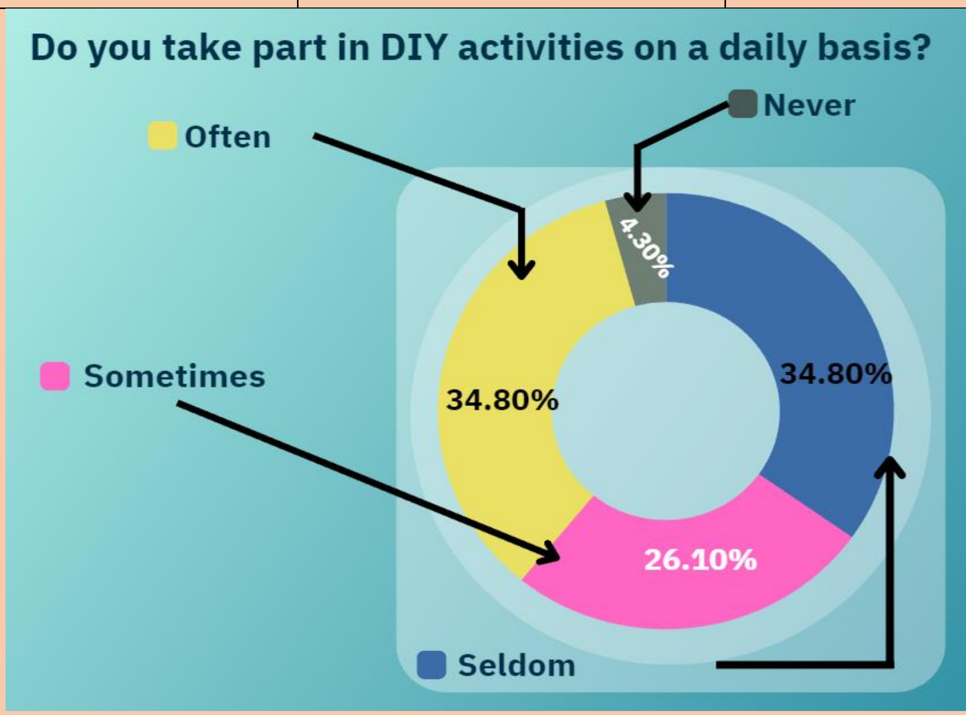

Table 19: Frequency of participation towards DIY activities

The findings presented in the table above aim to set out a general knowledge of the student's participation in DIY or do-it-yourself activities. The responses were categorised based on "often" participation to "never" participate in the DIY activities. Out of the total sample of 23 participants, the majority (34.8%) reported that they often engage in DIY activities on a daily basis, followed by 26.1% who said they do it sometimes. The same percentage of participants (34.8%) reported that they seldom engage in DIY activities on a daily basis. Only one participant (4.3%) reported never engaging in DIY activities. The frequency of Thai children's participation in DIY activities, as presented in Table 14, can be understood in light of several influencing factors given the age range of 5 to 20.

One key factor is the respondent's age and corresponding skill level, which was an issue that arose during the observation process. Younger children, typically needing more assistance and supervision, which was seen during the observations of the DIY activities, might not engage in DIY activities daily due to the limited availability of an assisting adult or elder sibling. Therefore, they may fall into the "seldom" category. Conversely, older respondents who have acquired greater skills, independence, and a higher degree of confidence in their abilities might engage more frequently, falling into the "often" or "sometimes" categories. Similarly, another element to consider is the varying interests and inclinations among the children. DIY activities span a broad spectrum, and not all children may be inclined towards these tasks. Some children may be more inclined towards other activities like sports, arts, or technology, which might explain the "seldom" and "never" categories. Furthermore, time constraints also play a crucial role. With schooling, homework, and other extracurricular activities, some children may need more time to engage in DIY activities regularly.

Lastly, access to resources, tools, and materials required for DIY tasks also influences their frequency of engagement. Those with easy access may be more likely to participate "often", while others may do so "seldom". With that said, the respondent's age and skill level, interests, time availability, and access to resources are some of the key factors influencing the frequency of Thai children's engagement in DIY activities.

2) What kind of things do you like to make?

Question	Findings
What kind of things do you like to make?	piggy bank invention
	Toy movie theatre
	shaded by blankets, paper dolls
	slime
	pony wings
	making sand bottles
	paper rocket
	Make a rocket, make a paper rabbit.
	something useful
	bicycle pipe
	Pop-up picture, fabric paint bag
	Artificial decorations for dogs
	likes to make toys
	Toy cardboard box, gun, ball shooting range

Table 20: Activities that participating children undertake.

The respondents provided a variety of answers, such as piggy banks, shadow boxes, paper dolls, slime, pinwheels, sand bottles, paper rockets, paper bunnies, useful items, bicycle tubes, pop-up pictures, painted fabric bags, decorative items for dogs, toys, and paper boxes for toys, guns, and soccer balls. The list is not organised in any particular order or category. However, it provides insights into the respondents diverse interests and preferences regarding DIY activities. These responses are also somewhat different in their level of specificity; for example, it is unlikely that the child responding "piggy banks" has made multiple piggy banks, but rather that they provided this as an example of what kind of product they might like to make. Thus, one of the reasons for the breadth of responses is likely due to these varying interpretations.

Analysing the findings further in collaboration with the sample size, table 15 reveals children's diverse interests and preferences regarding DIY activities. The broad range of responses, from piggy banks to paper rockets, underscores this age group's inherent creativity and imagination. This inherently shows that, as a child, several factors may contribute to these preferences. Firstly, age and developmental stages can greatly influence the type of activities that children find appealing. For example, younger children might be more attracted to activities involving tangible and immediate results, such as making slime or crafting a simple toy. Older children might lean towards more complex and challenging projects, like creating a paper rocket or an intricate pop-up picture. However, there was no obvious difference between children of different genders, with both boys and girls identifying a range of projects from simple to complex.

Moreover, another factor could be the influence of their surrounding environment and experiences. Children may be inclined to make objects they see in their daily lives, such as toys, or items they come across in school, books, or media, such as a toy movie theatre or paper dolls. Lastly, personal interest and curiosity also play a significant role. Some children might be naturally inclined towards artistic activities, thus leading to responses like "fabric paint bag" or "artificial decorations for dogs". In contrast, others might have a more practical or scientific bent, reflected in responses like "making something useful" or "paper rocket".

3) Do you find it easy to do DIY?

Answers	Frequency	Percentage
Very easy	6	26.10
Easy	13	56.50
Hard	3	13.00
Very hard	1	4.30
Total	**23**	**100.00**

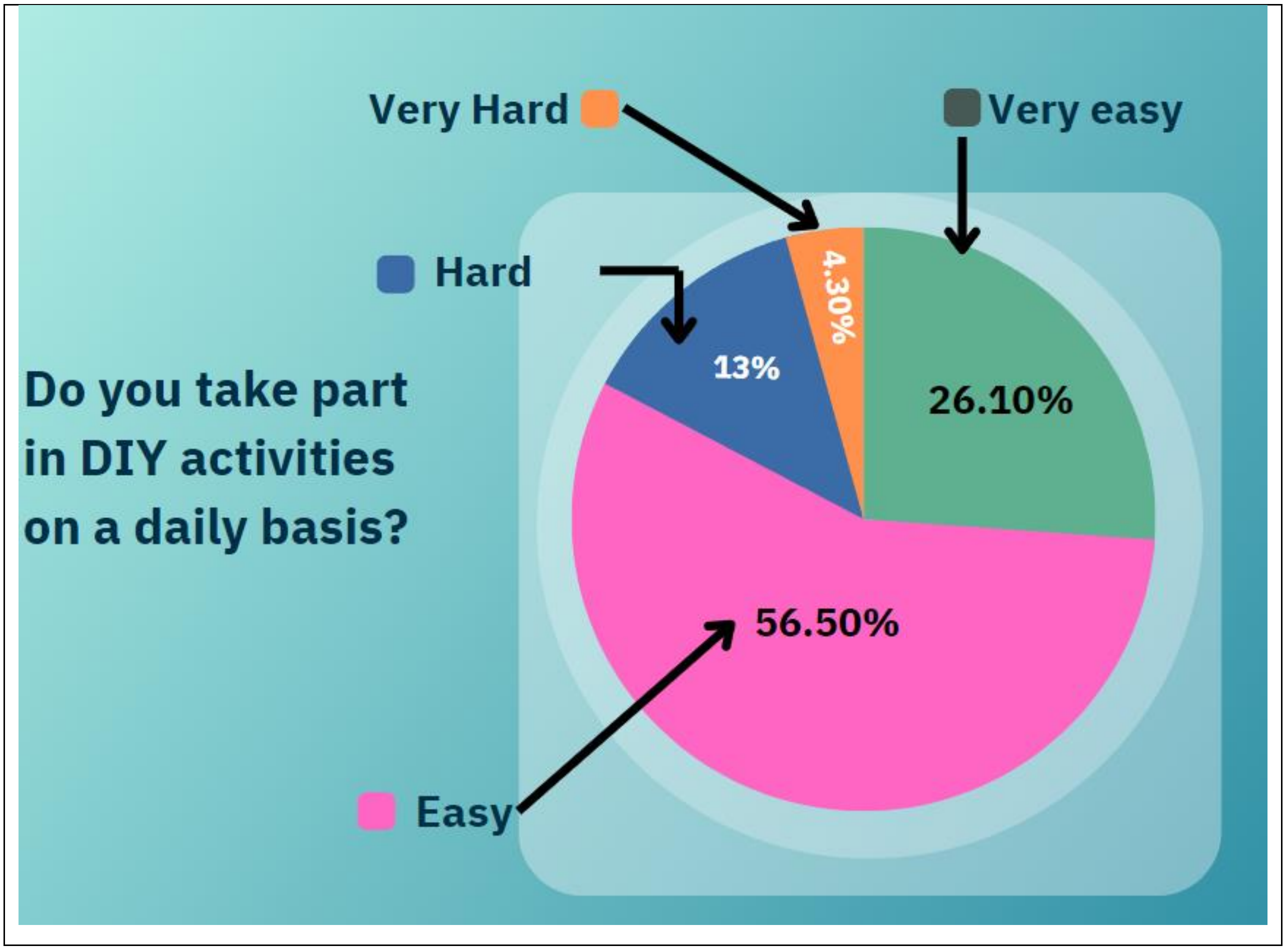

Table 21: Ease of Undertaking DIY: Responses of Children

The table presents data on respondents ease of doing DIY activities, represented by their answers categorised into four options: very easy, easy, hard, and very hard. The data were collected from a total of 23 respondents. Most respondents (56.50%) reported finding DIY activities easy to do, while 26.10% reported finding them very easy. A smaller percentage of respondents (13.00%) found DIY activities hard, and only 4.30% found it very hard to undertake DIY activities. There were no obvious links between the difficulty of DIY activities and factors such as age or gender. However, there could have been individual differences, for example, experience or physical coordination, which were not tested. The majority of the respondents found DIY activities to be easy/very easy to conduct.

4.2.1.3 Syringe Activity

The Syringe Activity comprised a series of tests associated with a syringe rocket activity. A syringe rocket (or vacuum rocket) is a relatively easy educational makerspace activity in which the end of the syringe is blocked in some way. The plunger is then pulled out, creating a vacuum that propels the rocket forward when the plunger is released (Day, 2019). This activity is relatively simple at a small scale, although larger syringe rocket builds tend to be failure prone. The NSM Enjoy Makerspace, a rocket syringe activity, used a small-scale syringe and target, increasing the chances of success while keeping the action sized for the space. The design for the rocket was communicated via iPadtablets in the makerspace, which explained the design, materials needed, and process and allowed children to investigate the possible effects of different methods. The use of tables was effective in the experimental approach, as it allowed ensuring that the instructions could be clearly delivered to the learners, and technological integration could be successfully achieved in during the learning process.

The questionnaire is associated with identifying the key learnings related to the "Syringe Rocket" makerspace activity. The respondents asked a total of 56 questions, divided across eight main segments using a Likert Scale approach. The Likert Scale approach allowed the respondents to score their opinions and attitudes from a score of 1 to 4, with one being the lowest and 4 being the highest. Further segmentation of the score is presented as follows.

Average	1.00 - 1.49	Disagree the most
Average	1.50 - 2.49	Disagree
Average	2.50 - 3.49	Agree
Average	3.50 - 4.00	Agree the most"

The table below performs a mean analysis of the responses, using a descriptive statistics analysis. The analysis is presented based on the scoring of 1.00 to 1.49 being strongly disagreeing a statement, 1.50 to 2.49 representing general disagreement, 2.50 to 3.49 representing general agreement, and 3.50 to 4.00 implying strong agreement to a statement.

Topic	Average	Conclusion
Overall Average	**3.34**	**Agree**
1. Family Learning	**3.17**	Agree
1.1 My family is involved within the group.	3.13	Agree
1.2 My family talks and doing activities together	3.30	Agree
1.3 My family has assistance with activities.	3.04	Agree
1.4 My parents have explained things to me.	3.22	Agree
1.5 My parents taught and guided me how to make Syringe Rocket in this activity.	3.17	Agree
2. Experiential Learning	**3.52**	**Strongly Agree**
2.1 You gained **intellectual skills** from the Enjoy Makerspace activity. For example, new knowledge and understanding.	3.52	Strongly Agree
2.2 You gained **problem solving** skills from the Enjoy Makerspace activity. For example, finding a solution to a problem in creating an object, selecting a way to repair a product, finding ways to complete the activity.	3.26	Agree
2.3 You gained **communication skills** from the Enjoy Makerspace activity. For example, listening to other people, expressing your ideas to others.	3.43	Agree
2.4 You gained **collaboration skills** from the Enjoy Makerspace activity. For example, sharing the material with others, helping other people to complete the task or collaborate as part of a team.	3.61	Strongly Agree
2.5 You gained **creative skills** from the Enjoy Makerspace activity. For example, learning how to make a new product or using specific tools.	3.78	Strongly Agree
3. Immersion	**3.30**	**Agree**
3.1 The Enjoy Makerspace held my attention.	3.48	Agree
3.2 I was focused on the Enjoy Makerspace.	3.57	Strongly Agree

Topic	Average	Conclusion
3.3 I felt I was separated from my real-world environment.	2.70	Agree
3.4 I found the Enjoy Makerspace activities challenging.	3.09	Agree
3.5 I felt motivated while doing the Enjoy Makerspace activities.	3.43	Agree
3.6 I felt emotionally attached to the Enjoy Makerspace activities.	3.43	Agree
3.7 I was disappointed when the activities at Enjoy Makerspace were complete.	3.43	Agree
4. Flow Experience	**3.07**	**Agree**
4. 1 The Enjoy Makerspace activities totally captured my attention.	3.61	Strongly Agree
4.2 I forgot about the progress of time.	3.09	Agree
4.3 I found the activities interesting.	3.61	Strongly Agree
4.4 I knew what I wanted to achieve.	3.52	Strongly Agree
4.5 The Enjoy Makerspace was boring for me.	**1.57**	**Disagree**
5. Learning STEM	**3.43**	**Agree**
Ø Science	**3.55**	**Strongly Agree**
5.1 You understand the scientific principles contained in the Syringe Rocket activity.	3.48	Agree
5.2 Making and playing Syringe Rocket will give you a better understanding of science.	3.52	Strongly Agree
5.3 You acquire scientific skills from the invention of the Syringe Rocket, such as observing, collecting data, experimenting or drawing conclusions.	3.52	Strongly Agree
5.4 By Making Syringe Rocket you enjoy learning science.	3.70	Strongly Agree
Ø Technology	**3.46**	**Agree**

Topic	Average	Conclusion
5.5 You have gained maker skills from the Syringe Rocket event.	3.43	Agree
5.6 You understand the technique Method and material selection for making the Syringe Rocket.	3.39	Agree
5.7 You understand the secret to making your Syringe Rocket more efficient at work.	3.57	Strongly Agree
5.8 You can apply techniques How to make a Syringe Rocket to tell others	3.48	**Agree**
Ø **Engineering**	**3.52**	**Strongly Agree**
5.9 You have learned how to play Syringe Rocket very well.	3.65	Strongly Agree
5.10 You understand how the Syringe Rocket works.	3.48	Agree
5.11 While you’ve made and tested Syringe Rocket, it crashes while playing. you can fix it	3.43	Agree
Ø **Mathematic**	**3.19**	**Agree**
5.12 Making of the Syringe Rocket allows you to practice mathematical skills such as measuring, calculating, predicting and comparing.	3.13	Agree
5. 13 Do you think this math skill made you good at making the Syringe Rocket?	3.09	Agree
5.14 This math skill gives you a better understanding of how the Syringe Rocket works, such as pressure and trajectory calculations.	3.04	Agree
5.15 How important do you think mathematics is in your study and daily life	3.52	Strongly Agree
6. Skills	3.50	**Strongly Agree**
Ø **Learning Skills**	3.54	Strongly agree
6.1 You get intellectual skills from Enjoy Maker Space activity. For example, ideas, thinking, making, listening.	3.74	Strongly agree

Topic	Average	Conclusion
6.2 You get problem solving skills from Enjoy Maker Space activity. For example, find the problem of making process, select variety ways for repairing or repair product of task completely.	3.61	Strongly agree
6.3 You get communication skills from Enjoy Maker Space activity. For example, listening to others, making yourself clear to others.	3.48	Agree
6.4 You get s collaboration skills from Enjoy Maker Space activity with your friends and family. For example, share the material with others, help other people to do task or collaborate with teamwork.	3.52	Strongly agree
6.5 You get creativity skill from Enjoy Maker Space activity. For example, make a new product or find a new way for making process.	3.39	Agree
Ø **Literacy Skills**	3.50	Strongly agree
6.6 You get information literacy skills from Enjoy Maker Space activity. For example, search more information from many media.	3.43	Agree
6.7 You get Technology Literacy skills from Enjoy Maker Space activity. For example, use computer and internet to complete task.	3.57	Strongly agree
Ø **Career and Life Skills**	3.47	**Agree**
6.8 You get flexibility and adaptability skills from Enjoy Maker Space activity. For example, adapt suitable tools and material for making process and product.	3.43	Agree
6.9 You get self-direction skills from Enjoy Maker Space activity. For example, plan to finish product and project.	3.48	Agree
6.10 You get social skills from Enjoy Maker Space activity with the toy with your friends and family. For	3.57	Strongly agree

Topic	**Average**	**Conclusion**
example, meeting new people, sharing, team working, introducing others.		
6.11 You get productivity skills from Enjoy Maker Space activity with the toy with your friends and family. For example, finish product of the project.	3.43	Agree
7. Inspiration	3.50	**Strongly agree**
7.1 Enjoy Maker Space activity makes you surprised.	3.57	Strongly agree
7.2 Enjoy Maker Space activity inspire you to do the other task of making.	3.52	Strongly agree
7.3 Enjoy Maker Space activity inspire you to develop more skills of maker in the future	3.57	Strongly agree
7.4 Enjoy Maker Space activity inspire you to do the bigger project in the future	3.48	Agree
7.5 You have positive attitudes with maker from Enjoy Maker Space activity	3.39	Agree
8. Creativity	3.24	**Agree**
8.1 You have creativity after join Enjoy Maker Space activity	3.26	Agree
8.2 Enjoy Maker Space activity prompted you to be creative	3.26	Agree
8.3 After you have joined with Enjoy Maker Space activity, you had innovative thoughts	3.22	Agree

Table 22: Learning from the “Syringe Rocket” makerspace activity

The findings of the table above have been reviewed based on the average opinion score of the respondents based on responses in the context of 8 key factors, including family learning, experiential learning, immersion, flow experience, STEM Learning, Skills, Inspiration, and Creativity. The average mean findings indicated that the overall average learning from the STEM learning had a mean value of 3.34, indicating that the Enjoy Makerspace had a positive effect on the learning experience of the respondents. The strongest agreement was presented in the context of experiential learning (mean = 3.52), which indicated that participating in the makerspace activity program had strongly contributed to experiential learning, which allowed in gaining skills such as creativity, collaboration, intellectual skills, communication skills, and problem-solving (in that order). Similarly, the factor of inspiration and skills had a mean = 3.50, indicating that the respondents agree that participating in the maker-space activity allowed for improving their overall learning-literacy-career skills and helped boost their creativity. Furthermore, it was found that the makerspace activity had facilitated an increase in motivation and inspiration in improving the individual's learning capabilities. Similarly, the remaining factors of the learning experience included learning STEM (mean = 3.43), immersion (mean = 3.30), creativity (mean = 3.24), family learning (mean = 3.14) and flow experience (mean = 3.07). The weakest significance of the makerspace activity was the flow experience, implying that the family had moderate assistance with the activity and involvement in the group.

4.2.1.4 The results of data analysis on the environment and factors that facilitate learning.

Considering your analysis of information about participating in the "Syringe Rocket" invention activity, what do you think about the environment and learning facilities? Two major and 7 minor items were analysed by considering the mean and interpretation criteria to rank the average opinion scores. Set the score range as follows.

Average	1.00 - 1.49	Least Agree
Average	1.50 - 2.49	mildly agree.
Average	2.50 - 3.49	Very agree.
Average	3.50 - 4.00	strongly agree.

Table below presents the mean values of the environment and facilities that facilitate learning.

Section	Average	Statement
Overall Respondent Opinion	**3.69**	**Strongly Agree**
1. Environment	**3.65**	**Strongly Agree**

Section	Average	Statement
1.1 The Environment in the Enjoy Maker Space area help your learning.	3.61	**Strongly Agree**
1.2 The atmosphere of Enjoy Maker Space area is suitable for your learning.	3.65	**Strongly Agree**
1.3 The tools and objects displayed in the Maker Space can help you craft the Syringe Rocket.	3.70	**Strongly Agree**
2. Resources	**3.73**	**Strongly Agree**
2.1 The Lecturer help you understand the process and skills of crafting the Syringe Rocket.	3.74	Strongly Agree
2.2 The Assistant Lecturer can help to explain how to craft the Syringe Rocket until you can complete it.	3.61	Strongly Agree
2.3 The materials for invention are suitable and sufficient for the invention of the Syringe Rocket.	3.78	Strongly Agree
2.4 Syringe Rocket activity manual can make it easier for you to understand and craft.	3.83	Strongly Agree

Table 23: Mean values of the environment and facilities that facilitate learning.

The table above presents the mean values for the environment and learning facilities with the "Syringe Rocket" invention activity. The overall respondent opinion is 3.69, indicating a strong agreement with the environment and learning facilities. The mean score for the environment is 3.65, indicating a strong agreement that the Enjoy Maker Space area is conducive to learning, with a suitable atmosphere for learning. The tools and objects displayed in the Maker Space are also seen as helpful in crafting the Syringe Rocket, with a mean score of 3.70. Regarding resources, the mean score is 3.73, indicating a strong agreement that the lecturer is helpful in understanding the process and skills of crafting the Syringe Rocket. The invention's materials are considered suitable and sufficient, with a mean score of 3.78. The Syringe Rocket activity manual is also seen as helpful in understanding and crafting the rocket, with a mean score of 3.83. Hence, the analysis suggests that the environment and learning facilities are well-suited for the "Syringe

Rocket" invention activity, with strong agreement that the Enjoy Maker Space area and the resources provided help learn and craft the rocket.

4.2.1.5 What is your opinion about today's invention activity?

Table below shows your feedback on the invention activity that took place at the makerspace activity NSM.

Topic	Comments
Opinions regarding the invention activity by respondents	It was very fun!
	It was fun and easy to understand but challenging enough to keep us engaged. It was motivating and inspiring for the activity.
	The activity was enjoyable, and the speaker explained it well.
	Having fun and feeling happy while making the Syringe Rocket.
	It was a delightful and enjoyable activity.
	It was a really good activity.

Table 24: Feedback on Invention Activity

Table 19 sheds light on children's feedback regarding the Syringe Rocket invention activity at the NSM makerspace. The young respondents found the activity highly enjoyable, gleaned from their responses. The unanimous expression of fun underscores the effectiveness of this hands-on, experiential learning approach in engaging children and enhancing their interest in invention and making activities.

Furthermore, the feedback indicates an appropriate balance between comprehension and challenge in the activity. The children found the project easy to understand and crucial in preventing frustration or disinterest. Meanwhile, the task was not too complicated and had some degree of difficulty that is important for keeping interest and producing problem-solving skills. In addition, another feature emphasized by the children was the motivational and inspirational character of the activity. This indicates the force of such physical activities that can lead to curiosity and interest in learning, which is the foundation of the lifelong inclination to STEM areas.

Conversely, another important element found in the feedback of the children was the manner in which the facilitator or speaker explained the activity. Children often learn technology best with clear instructions and guidance (Kay and Knaack, 2007), so the speaker's ability to effectively convey the information likely contributed to the children's positive experiences. This highlights the importance of effective facilitation in educational activities involving children.

All in all, the children's feedback suggests that the Syringe Rocket activity successfully provided an engaging, challenging, and motivational learning experience that was well-guided, all of which contributed to the overall enjoyment of the project.

4.2.1.6 Summary of Research Findings from EMSLOQ: For Children

The EMSLOQ survey on the NSM Enjoy Makerspace activity for children revealed that most respondents were male, aged 10-12 years old, and attending primary school. Respondents reported frequent participation in DIY activities and found them easy to undertake. Following participation in the Syringe Rocket activity, respondents perceived the highest level of learning in this aspect, followed by skills and inspiration, STEM learning, intention to learn, creativity, family learning, and enjoyment, respectively. Furthermore, the instructors, assistant instructors, materials, and manuals were deemed the most significant factors in the learning environment and facilities for participants. The Enjoy Makerspace room's various environmental factors were also found to facilitate new learning. Overall, the Syringe Rocket activity was perceived as an enjoyable and informative experience, with the instructors and assistant instructors effectively explaining the activity. At the same time, participants were able to learn science concepts embedded within it while enjoying competition with other participants.

4.2.2 NSM Enjoy Makerspace Learning Outcomes Questionnaire *(*EMSLOQ*):* Adults

4.2.2.1 Demographic Findings

The table below shows the number and percentage of the status of respondents in terms of age. It is notable that there were no parents younger than 30 within the respondents. This is due to the combination of small sample size and the fact that families with younger children were excluded to make sure they could enjoy the Makerspace activities rather than attending to the survey. Therefore, younger parents were excluded.

Age	Frequency	Percent
30 – 39 year	7	30.40
40 – 49 year	13	56.50
50 – 59 year	1	4.30
Other	2	8.70
Total	**23**	**100.00**

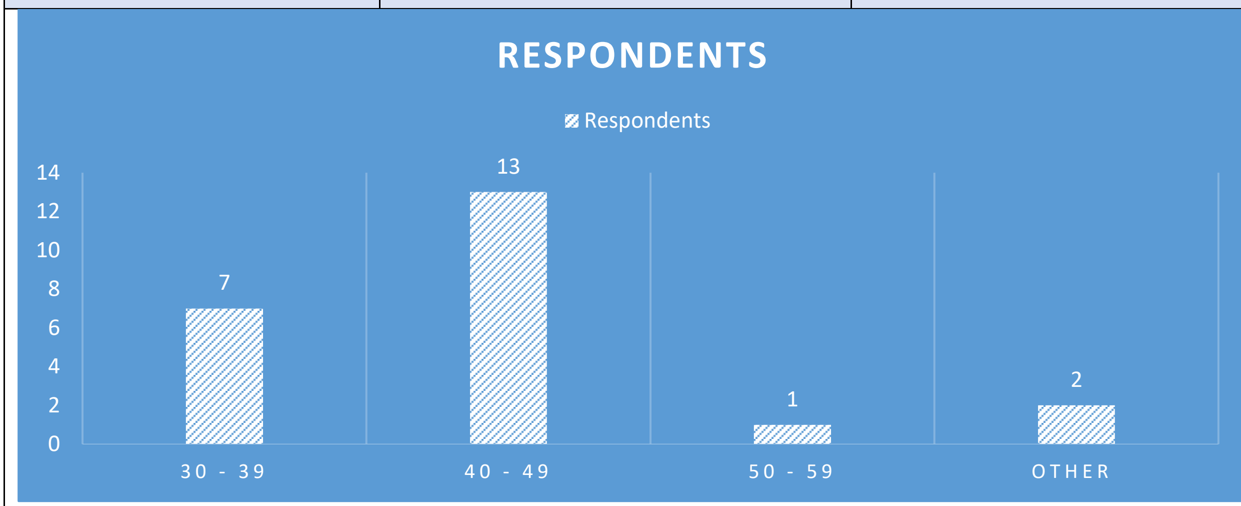

Table 25: Age of Respondents of Adults

The table shows the respondents general status regarding their age. A total of 23 respondents participated in the survey, with the majority being in the age range of 40 - 49 years old (56.50%). The second largest age group is 30 - 39, accounting for 30.40% of the respondents. There is only one respondent (4.30%) in the age group of 50 - 59 years old, while the remaining 8.70% are categorised as "Other". Overall, the majority of the respondents in the survey are in their 40s and 30s.

Next is on the gender of the adult respondents.

Sex	Frequency	Percent
Male	10	43.50
Female	13	56.50
Total	**23**	**100.00**

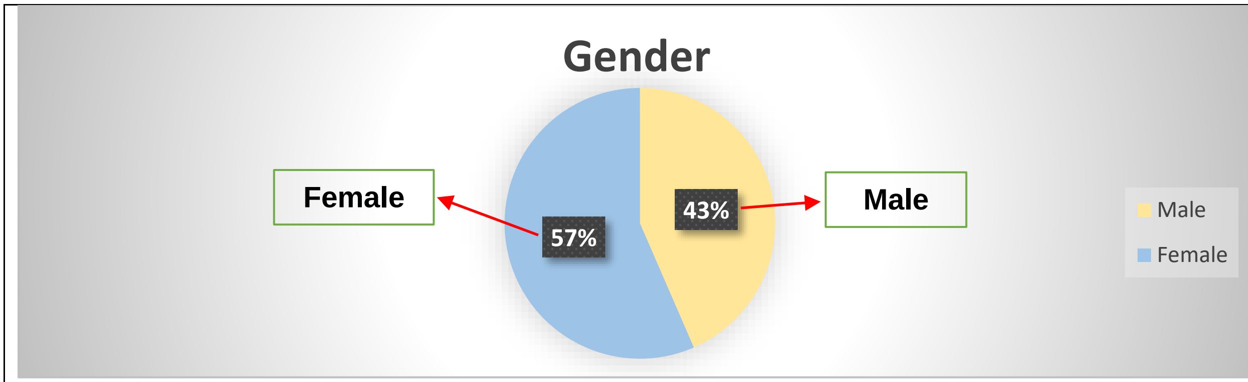

Table 26: Gender of Respondents of Adults

The table displays the general status of respondents based on their gender. Of the 23 respondents, ten were male, accounting for 43.5%, while 13 were female, accounting for 56.5% of the sample. This difference can be accounted for by two factors. Firstly, there were some families accompanied by only one parent, and when this occurred it was most commonly a mother or grandmother. In groups with more than one parent, it was slightly more common for women to fill out the survey. This could be associated with a slightly higher tendency of women to participate in social surveys (Smith, 2009).

Education	Frequency	Percent
Bachelor Degree	17	73.90
Master's degree.	6	26.10
Total	**23**	**100.00**

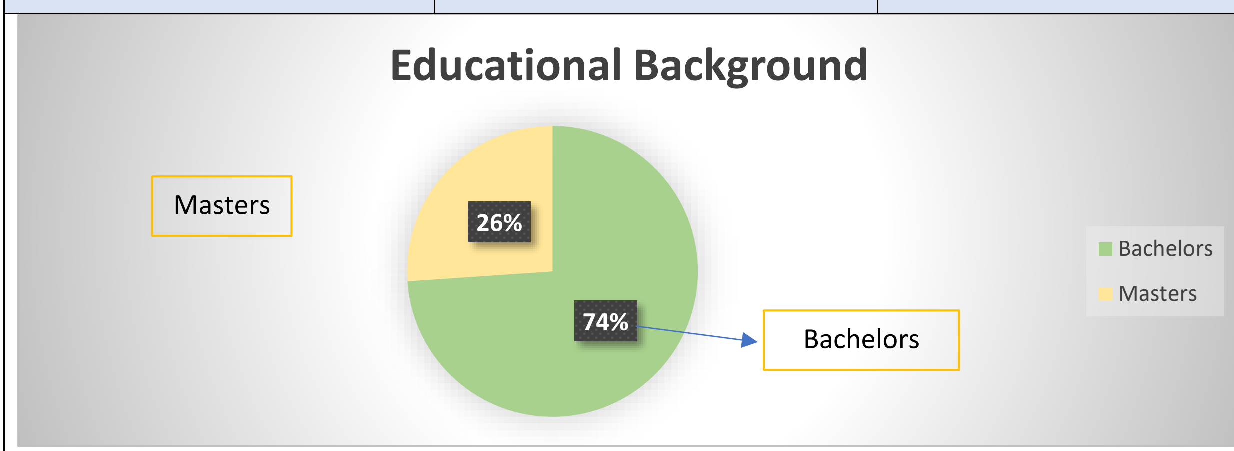

Table 27: Educational Background of the Respondents of adults

The table shows the education level of the respondents, with 73.9% holding a bachelor's degree and 26.1% holding a Master's degree. The total number of respondents was 23. This indicates that most respondents have completed higher education, which may impact their perceptions and responses in the survey.

4.2.2.2 Analysis of data on interest in the Enjoy Makerspace activity.

1) Do you take part in DIY (Do it yourself) activities on a daily basis?

Title	Frequency	Percent
Often	12	52.20
Sometimes	8	34.80
Seldom	2	8.70
Never	1	4.30
Total	**23**	**100.00**

Table 28: Do you take part in DIY (Do it yourself) activities on a daily basis?

The table shows the frequency and percentage of respondents interest in the Enjoy Makerspace activity. Out of 23 respondents, 12 (52.2%) reported often having an interest in the activity, while 8 (34.8%) reported sometimes having an interest. Only 2 (8.7%) respondents reported seldom having an interest, and 1 (4.3%) reported never having an interest in the activity. Overall, most respondents reported having some level of interest in the Enjoy Makerspace activity, with more than half indicating a frequent interest.

After evaluating the above table and the following findings (presented in the next sections), the above findings can be analysed from a generalisation perspective. Firstly, the survey results align well with the demographic profile of the respondents, who are Thai adults within the age group of 30 - 59 years and most likely parents. Given the respondents preferences for DIY activities, as demonstrated in previous responses, it is not surprising that a significant percentage (52.2%) reported frequently participating in DIY activities like those offered at Enjoy Makerspace. The varied DIY activities align with the respondents interest in home improvement, crafting, gardening, and other practical tasks. Such activities provide a platform for their interests and offer practical skills that can be applied in their daily lives, enhancing their confidence and independence. In addition, as parents, these adults might be actively looking for educational and engaging activities to do with their children or even on their own for personal enrichment. Enjoy Makerspace, which focuses on creativity and hands-on learning, could be an attractive option that meets these needs. It allows them to explore new skills and ideas, stimulate their creativity, and bond constructively and enjoyably with their children. The 34.8% who sometimes participate in DIY activities might represent those with interest but are limited by other constraints such as time, access, or competing responsibilities. It is also possible that this group is less comfortable or experienced with DIY activities and, therefore, participates less frequently. However, the small percentage of respondents who seldom or never participate in DIY activities could be due to a lack of interest or perceived relevance, or they might find these activities too challenging. Alternatively, they might have other interests or commitments that take precedence.

Therefore, the high level of interest in Enjoy Makerspace activities among this group likely reflects the alignment of these activities with their interests, needs, and lifestyle factors, as well as the perceived benefits for themselves and their families.

2) DIY Activity You Like the Most to Invent

Topic	**Responses**
The DIY activity you like to invent the most.	Everything on electronic appliances, repairs
	Dough moulding, making useful items
	Power tools, assisting with moving objects
	Repairs of household equipment, plumbing, electricity, appliances
	Dollhouse
	Paper toys
	Knitting for hanging planters
	Plant pots and automatic watering equipment
	Lampshades
	Household items

Topic	Responses
	Home-related equipment
	Vase for flowers
	Household appliances
	Furniture
	DIY clothing and accessories
	Storage boxes
	Learning-related equipment
	DIY activities with paper.

Table 29: DIY Activity You Like the Most to Invent

Upon examining Table 24, the DIY activities respondents enjoy most span a broad spectrum. However, a few common themes can be identified.

Many respondents expressed an interest in home improvement and repair activities, such as working on electronic appliances, plumbing, electricity, and general household equipment. This could indicate that many respondents derive satisfaction from being able to maintain and improve their living environment. It may also reflect a practical consideration, as the ability to perform such tasks can be cost-saving and convenient. In addition to that, the responses of the study indicated that the respondents had agreed that the Do-It-Yourself (DIY) activity was a popular category under the crafting and artistic activities, evidenced by tasks such as - dough-moulding, crafting paper toys, knitting, and creating DIY clothing/ accessories. Furthermore, delving into the behaviour of the respondents, it can be noted that some actions and activities, such as crafting vase for flowers, creating lampshades, and crafting plant pots and watering equipment, indicates the respondent’s interest in outdoor activity. Furthermore, these activities also reflect the aesthetic preferences of the respondents, which can be used in interpreting their style and preferences. Some also are preferential based on their professional or personal hobbies and characteristics.

Lastly, several respondents preferred creating learning-related equipment and storage boxes. This could reflect the needs of respondents with children, who are looking for cost-effective and customised solutions for education and organisation at home. Therefore, the respondents preferences reflect a wide range of interests, needs, and lifestyle factors. However, they all share an appreciation for DIY activities practical and creative aspects.

3) Ease of DIY for respondents

Title	Frequency	Percentage
Very easy	6	26.10
Easy	15	65.20
Hard	2	8.70
Total	**23**	**100.00**

Table 30: Respondents Response on easy are their DIY

The table indicated above indicates the categorisation of DIY things that the respondents prefer to make, ranging from very easy stuff to hard things. The responses indicated that the majority of the respondents were interested in earning easy DIY things (65.20%). The categorisation of the easy tasks of DIY activities could include dough moulding, repair of household equipment, home-related equipment, vase equipment, learning-related equipment, and other. Here, the very easy tasks could relate to DIY clothing and accessories, DIY activities with paper, doll houses, paper toys, and knitting for hangers and plants. In addition to that, some hard tasks, such as DIY projects, include the use of power tools, electronic appliances and repairs, and others. In addition to the factors mentioned above, it can be noted that cultural factors could also be a key determinant influencing the preferences for DIY activities. In Thailand, as in many cultures, handicrafts and DIY activities are integral to traditional life and education. From a young age, many individuals are introduced to tasks that require manual dexterity and problem-solving, contributing to their comfort and ease with such activities in adulthood.

Moreover, it is worth noting that the respondents are from an educational setting where they are encouraged to engage in hands-on learning activities like the Syringe Rocket activity. This exposure could increase their confidence and skill in managing DIY tasks, lowering their perceived difficulty. Finally, framing DIY activities as educational and fun, as in the case of the Enjoy Makerspace, might influence how the problem is perceived. When an action is engaging, and the result is rewarding, participants may perceive the task as less difficult due to their high level of motivation and enjoyment.

4.2.2.3 Analysis of data on perceptions of learning outcomes from participating in the "Syringe Rocket" activity

After participating in the "Syringe Rocket" activity, respondents perceived the highest level of learning in this aspect, followed by skills and inspiration, STEM learning, intention to learn, creativity, family learning, and enjoyment, respectively.

After considering the data analysis related to participating in the "Syringe Rocket" activity, how do you think about learning from this activity? The analysis consists of 8 major items and 56 sub-items, considering the mean and interpretation criteria to arrange the average score of opinions. The score ranges are set as follows:

Average	1.00 - 1.49	Strongly Disagree
Average	1.50 - 2.49	Disagree
Average	2.50 - 3.49	Agree
Average	3.50 - 4.00	Strongly Agree

Table below shows the average values of participating in the "Syringe Rocket" activity and opinions about learning from the activity.

Topic	Average	Significance
Overall opinions of survey respondents	**3.55**	Strongly agree
1. Family learning	**3.59**	Strongly agree
1.1 Your family participates together in the group	3.57	Strongly agree
1.2 Your family talks and does activities together	3.65	Strongly agree
1.3 Your family helps each other in doing activities	3.61	Strongly agree
1.4 Your family explains various things to you	3.57	Strongly agree
1.5 Your family teaches and guides you on how to make a Syringe Rocket in this activity	3.57	Strongly agree

Topic	Average	Significance
2. Learning experiences	**3.65**	**Strongly agree**
2.1 You gain thinking skills, such as new knowledge and understanding in science and technology	3.70	Strongly agree
2.2 You acquire problem-solving skills, such as finding ways to solve problems in creating a project, choosing methods for repairing projects, and finding ways to complete activities	3.57	Strongly agree
2.3 You gain communication skills, such as listening to others and expressing your opinions to others	3.65	Strongly agree
2.4 You gain teamwork skills from this activity, such as sharing information and helping each other to complete tasks successfully.	3.65	Strongly agree
2.5 You gain creative thinking skills from the Syringe Rocket activity, such as learning new ways to create workpieces or using specific tools.	3.70	Strongly agree
3. Motivation in participating in the activity	**3.57**	**Strongly Agree**
3.1 The Syringe Rocket activity helps you become more focused.	3.78	Strongly agree
3.2 You are attentive to the activity and the atmosphere in the Maker Space while participating.	3.74	Strongly agree
3.3 When doing the Syringe Rocket activity, you feel disconnected from the real world.	3.39	Agree
3.4 You think the Syringe Rocket activity is challenging.	3.39	Agree
3.5 You feel motivated to participate in the Syringe Rocket activity.	3.39	Agree
3.6 You feel impressed and attracted to the Syringe Rocket activity.	3.61	Strongly agree

Topic	**Average**	**Significance**
3.7 You don't want the Syringe Rocket activity to end.	3.70	Strongly agree
4. Enjoyable experience	**3.24**	**Agree**
4.1 The Syringe Rocket activity motivates you to create a workpiece.	3.65	Strongly agree
4.2 You become so engrossed in creating the Syringe Rocket that you lose track of time.	3.57	Strongly agree
4.3 You find the Syringe Rocket activity interesting.	3.74	Strongly agree
4.4 The Syringe Rocket activity is fun and enjoyable.	3.87	Strongly agree
4.5 The Syringe Rocket activity makes you feel bored.	1.39	Strongly Disagree
5. STEM Learning	**3.62**	Strongly agree
Science	**3.65**	Strongly agree
5.1 You understand the scientific principles behind the Syringe Rocket activity.	3.52	Strongly agree
5.2 Creating and experimenting with the Syringe Rocket helps you better understand science.	3.61	Strongly agree
5.3 You gain scientific skills from creating the Syringe Rocket, such as observation, data collection, experimentation, or drawing conclusions.	3.74	Strongly agree
5.4 Creating and playing with the Syringe Rocket makes you enjoy learning about science.	3.74	Strongly agree
Technology	**3.66**	Strongly agree
5.5 You gain skills in designing and inventing through the Syringe Rocket activity.	3.74	Strongly agree
5.6 You understand techniques, methods, and material selection in creating the Syringe Rocket.	3.70	Strongly agree
5.7 You understand the tips for making your Syringe Rocket more efficient in its operation.	3.61	Strongly agree

Topic	Average	Significance
5.8 You can transfer and share the techniques and methods of creating a Syringe Rocket with others.	3.61	Strongly agree
Engineering	**3.68**	Strongly agree
5.9 You have learned how to play Syringe Rocket very well.	3.70	Strongly agree
5.10 You understand the working mechanism of the Syringe Rocket.	3.65	Strongly agree
5.11 When you create and experiment with the Syringe Rocket, you can solve problems that occur while playing.	3.70	Strongly agree
Mathematics	**3.52**	**Strongly Agree**
5.12 Creating a Syringe Rocket allows you to practice mathematical skills such as measuring, calculating, estimating, and comparing.	3.43	Agree
5.13 You think these mathematical skills help you create a better Syringe Rocket.	3.52	Strongly agree
5.14 These mathematical skills help you better understand the workings of the Syringe Rocket, such as pressure and calculating the trajectory.	3.43	Agree
5.15 How important do you think mathematics is in education, learning, and everyday life?	3.70	Strongly agree
6. Skills	**3.50**	Strongly agree
Learning Skills	**3.54**	Strongly agree
6.1 You get intellectual skills from Enjoy Maker Space activity. For example, ideas, thinking, making, listening.	3.65	Strongly agree
6.2 You get problem solving skills from Enjoy Maker Space activity. For example, find the problem of making process, select variety ways for repairing or repair product of task completely.	3.61	Strongly agree

Topic	**Average**	**Significance**
6.3 You get communication skills from Enjoy Maker Space activity. For example, listening to others, making yourself clear to others.	3.48	Agree
6.4 You get s collaboration skills from Enjoy Maker Space activity with your friends and family. For example, share the material with others, help other people to do task or collaborate with teamwork.	3.43	Agree
6.5 You get creativity skill from Enjoy Maker Space activity. For example, make a new product or find a new way for making process.	3.57	Strongly agree
Literacy Skills	**3.43**	Agree
6.6 You get information literacy skills from Enjoy Maker Space activity. For example, search more information from many media.	3.43	Agree
6.7 You get Technology Literacy skills from Enjoy Maker Space activity. For example, use computer and internet to complete task.	3.43	Agree
Career and Life Skills	**3.52**	**Strongly agree**
6.8 You get flexibility and adaptability skills from Enjoy Maker Space activity. For example, adapt suitable tools and material for making process and product.	3.35	Agree
6.9 You get self-direction skills from Enjoy Maker Space activity. For example, plan to finish product and project.	3.65	Strongly agree
6.10 You get social skills from Enjoy Maker Space activity with the toy with your friends and family. For example, meeting new people, sharing, team working, introducing others.	3.52	Strongly agree

Topic	Average	Significance
6.11 You get productivity skills from Enjoy Maker Space activity with the toy with your friends and family. For example, finish product of the project.	3.57	Strongly agree
7. Inspiration	**3.60**	Strongly agree
7.1 Enjoy Maker Space activity makes you surprised.	3.57	Strongly agree
7.2 Enjoy Maker Space activity inspire you to do the other task of making.	3.57	Strongly agree
7.3 Enjoy Maker Space activity inspire you to develop more skills of maker in the future	3.57	Strongly agree
7.4 Enjoy Maker Space activity inspire you to do the bigger project in the future	3.65	Strongly agree
7.5 You have positive attitudes with maker from Enjoy Maker Space activity	3.70	Strongly agree
8. Creativity	**3.65**	Strongly agree
8.1 You have creativity after join Enjoy Maker Space activity	3.61	Strongly agree
8.2 Enjoy Maker Space activity prompted you to be creative	3.70	Strongly agree
8.3 After you have joined with Enjoy Maker Space activity, you had innovative thoughts	3.65	Strongly agree

Table 31: Average values of participating in the “Syringe Rocket” activity and opinions about learning from the activity.

This table presents the survey results on various aspects of the Syringe Rocket activity in the Enjoy Maker Space. The responses are measured on a scale of 1 to 4, with one being “strongly disagree” and four being “strongly agree”. The topics covered include family learning, learning experiences, motivation, enjoyment, STEM learning, skills, inspiration, and creativity. The average score and the significance level of agreement for each topic are shown.

The key takeaways from this table are, firstly, the survey respondents relished a gratifying experience (average 3.55) with the Syringe Rocket activity. The participants emphatically concurred that family learning (average 3.59), enriching learning experiences (average 3.65), and STEM learning (average 3.62) constituted significant facets of the activity. Furthermore, they wholeheartedly agreed that they acquired a diverse range of skills, encompassing learning (average 3.54), literacy (average 3.43), and career and life skills (average 3.52) from the activity. Therefore, it does not focus solely on STEM learning but also aids in the development of literacy, career, and life skills. This multifaceted approach is crucial in preparing participants for a wide range of future challenges in both academic and real-world contexts.

The motivation to partake in the activity was elevated (average 3.57), rendering the experience delightful (average 3.24). The action acted as a catalyst for creativity (average 3.65) and cultivated a positive disposition towards making and innovation. The high motivation and enjoyment scores indicate that the participants found the activity intrinsically rewarding. This could suggest that hands-on, creative projects like the Syringe Rocket activity are not just effective teaching tools but can also foster a genuine enthusiasm for learning. This intrinsic motivation and enjoyment are key drivers for long-term engagement and learning retention.

Therefore, from this outcome, the Syringe Rocket activity in the Enjoy Maker Space has been lauded by the participants, proffering an enjoyable and stimulating learning experience while fostering various indispensable skills and nurturing creativity.

4.2.2.4 Results of the data analysis related to the environment and factors that facilitate learning.

When considering the data analysis regarding participation in the "Syringe Rocket" invention activity, on the question "what are your thoughts about the environment and the factors that facilitate learning?" The analysis is divided into 2 main points and 7 sub-points, taking into account the average values and the criteria for interpreting the meaning to rank the average opinion scores. The score ranges are as follows:

Average	1.00 - 1.49	Strongly disagree.
Average	1.50 - 2.49	Disagree
Average	2.50 - 3.49	Agree
Average	3.50 - 4.00	Strongly agree.

Table below shows the average values of the learning environment and factors that facilitate learning.

Section	Average	Significance
Overall opinions of the survey respondents.	**3.69**	Strongly agree
1. Environment	**3.65**	Strongly agree
1.1 The Environment in the Enjoy Maker Space area help your learning.	3.61	Strongly agree
1.2 The atmosphere of Enjoy Maker Space area is suitable for your learning.	3.65	Strongly agree
1.3 The tools and objects displayed in the Maker Space can help you craft the Syringe Rocket.	3.70	Strongly agree
2. Resources	**3.73**	Strongly agree
2.1 The Lecturer help you understand the process and skills of crafting the Syringe Rocket.	3.74	Strongly agree
2.2 The Assistant Lecturer can help to explain how to craft the Syringe Rocket until you can complete it.	3.61	Strongly agree
2.3 The materials for invention are suitable and sufficient for the invention of the Syringe Rocket.	3.78	Strongly agree
2.4 Syringe Rocket activity manual can make it easier for you to understand and craft.	3.83	Strongly agree

Table 32: Environment and Factors that facilitate learning.

The findings show that participants were highly satisfied with the learning environment and resources provided during the Syringe Rocket activity in the Enjoy Maker Space area. They didn’t question that the environment, ambiance, and tools were ideal for studying and making the Syringe Rocket. Additionally, support from the lecturer and assistant lecturer were valued by the participants. The materials and activity manual were perceived by them as appropriate and helpful in understanding the Syringe Rocket project and in completing them successfully. As far as the side of environment is concerned the respondents agreed very strongly, an average score of 3. 65. This means the organization, environment, and tools offered in the Makerspace helped them to learn, with the learning process being more interactive and productive. An enabling environment is an important factor that helps in promoting creativity and active participation, an achievement that has been made in this case.

In terms of the resources offered, they were rated as very effective, scoring 3.73 out of 4. These resources would have included the components needed for the Syringe Rocket activity, teacher guides, and extension activities for ongoing learning. This high mark signifies the sufficiency and appropriateness of these resources in enabling participants to effectively participate in and finish the Syringe Rocket activity. It underscores the role of well-thought-out resources in helping students to accomplish the task at hand and also to understand the underlying ideas and acquire appropriate skills.

The high scoring of both environment and resources is the evidence of the success of the Enjoy Mekerspace in general. Knowledgeable instructors, supportive environment and the availability of comprehensive learning resources all together make the learning process both effective and enjoyable.

Nevertheless, it should be remembered that there is always something that can be improved. The average scores are however very high, and responses from the participants that score low in these areas could be of great benefits in improving future activities. What are some specific factors that could be linked towards the low scores and how do the participants feel about the low score they received in the feedback? With the ongoing collection and analysis of the responses, reworking these elements will contribute only to the improvement of the performance in the Enjoy Makerspace as a whole.

4.2.2.5 Overall Opinion

The following table provides the overall respondent opinions:

Section	Respondent Statements
Responses	Great job giving children the opportunity to think, learn, and practice using tools.
	This is an activity that is fun and allows learning to happen at the same time.
	Teachers, staff, and experts provide excellent knowledge and guidance for this activity.
	Children have fun using tools on their own, building confidence in themselves.
	Children get to try thinking and predicting the flight of a rocket, creating excitement and challenge for everyone in the family to help and discuss together.
	This activity is suitable for children, helping them to have creative thinking, imagination, and learning more.
	Have fun inventing with small items today, even if it doesn't go far. Designing what kind of rocket to make and doing the activity together with the family as if going back to childhood again. Thank you for this fun activity.
	Want more activities like this.
	Like activities that allow children to do things themselves.
	Helps families have activities to build relationships with each other more.
	Helps increase skills in the family.
	Children are interested, have fun, and receive knowledge in science. They can solve specific problems.
	Fun and adds to learning skills.
	Every staff member provides great knowledge and guidance throughout the experiment.

Section	Respondent Statements
	Like activities that have competition with friends in the room, making interactions with other participants.

Table 33: Overall Opinion Adults

Summary of research findings from the NSM Enjoy Makerspace (EMSLOQ) activity learning outcomes for adults:

The activity clearly fosters creativity and learning, with adults noting that it provides a platform for children to think, learn, and practice using tools while having fun. One respondent highlighted, "Great job giving children the opportunity to think, learn, and practice using tools." The duality of being an entertaining and educational activity is its unique selling proposition. This means such hands-on activities are not only fun but significantly contribute to STEM learning and creativity development in children.

In terms of staff contribution, the role of teachers, staff, and experts was highly appreciated by the respondents. As one participant aptly put it, “Teachers, staff, and experts provide excellent knowledge and guidance for this activity”. They were acknowledged for their excellent knowledge and guidance. This feedback underscores the importance of skilled facilitators in delivering such interactive and educational experiences. The quality of the instructors and materials significantly enhances the learning outcomes for participants.

The Syringe Rocket activity also emerged as a family-centric experience, providing a unique opportunity for family members to engage, interact, and learn together. Reflecting on this, a respondent mentioned, “Children get to try thinking and predicting the flight of a rocket, creating excitement and challenge for everyone in the family to help and discuss together”. Respondents highlighted the benefits of family learning and relationship building that the activity facilitated. This suggests that incorporating such family-inclusive elements can boost participation and engagement rates in similar activities in the future.

Moreover, the aspect of competition added an element of excitement and interaction among participants, with feedback like, “Like activities that have competition with friends in the room, making interactions with other participants”, suggesting that competitive features could be beneficial to include in future activities to promote active participation and enhance learning outcomes.

Regarding outliers or unusual feedback, the data provided does not indicate any explicit negative responses or particularly unique perspectives. However, for a more comprehensive view, it would be helpful to analyse the responses that fall outside the consensus or significantly deviate from the average feedback. Also, potential points of improvement or dissatisfaction lie in areas not directly covered by the survey, such as scheduling, access, or cost, which requires additional information to be fully analysed.

Next, the demographic information indicates that the majority of respondents were educated women in their 40s who enjoy DIY activities. This insight may be useful for future marketing and programming decisions, as it suggests this demographic may be particularly interested in similar educational, hands-on activities. “Like activities that allow children to do things themselves”, was a sentiment echoed by several participants, indicating a strong preference for activities that promote independence and hands-on learning. Still, to avoid bias and ensure inclusivity, it would be beneficial to explore how the activity and future similar activities can be made appealing and accessible to a broader demographic.

4.2.3 Correlation Analysis

In addition to the descriptive statistics analysis presented in the findings above, the correlation analysis has further been performed. The correlation analysis is presented to analyse the inter-relationship between the 7 key variables including, family experience, experiential learning, immersion, learning experience, STEM learning, skills, inspiration, and creativity. In addition to that, the variable associated with learning and experience in the Syringe Rocket creation, and environment + resources were taken into consideration.

The correlation analysis was performed with a total of 23 children's data and presented as follows.

	1	2	3	4	5	6	7	8	9	10
Family	1									
Experiential	.435*	1								
Immersion	.610*	.556*	1							
Experience	.120	.337	.631**	1						
STEM	.248	.496*	.600*	.691**	1					
Skills	-.004	-.120	.130	-.212	-.049	1				
Inspiration	-.231	-.257	-.349	.004	-.015	.071	1			
Creativity	.095	.340	.402	.526*	.825**	-.169	.040	1		
Syringe	.612*	.671**	.858**	.706**	.849**	.014	-.070	.690**	1	
EF	.200	.414*	.299	.343	.655**	-.182	-.192	.526*	.499*	1

Table 34: Correlation Analysis - Children

Using a significance measure of 0.05 (5%), the findings of this study indicated that family learning experience had a significant correlation with experiential learning (r = 0.435), immersion in the learning experience (r = 0.610), and syringe-rocket learning activity (r = 0.612). Hence, it can be stated that, when working with the family, children are likely to have an enjoyable experience in participating and conducting activities, such as the syringe-rocket activity. It was also noted that family learning among children is expected to improve the immersive learning experience and contribute to experiential learning. Secondly, it can be noted that experiential learning (2) among children can positively affect the immersive learning experience (r = 0.556), STEM learning (r = 0.496), activities like Syringe-Rocket (r = 0.671), and environment and resources (r = 0.414). It was noted that experiential learning could increase the learning acquired from real-time practical maker-space activities such as making syringe rockets.

Furthermore, experiential learning also contributed to STEM learning, with the increased understanding of principles and techniques associated with the syringe- rocket development. Thirdly, the immersion factor correlated with an improved experience in STEM learning and is the strongest correlated factor with the makerspace activity of Syringe-Rocket. This implies that a greater level of immersion can lead to an increase in the preference for engaging in maker-space activities. Hence, to ensure increased learning, makerspace should ensure that their actions have increased immersion. The immersion factor can be defined based on how selected activities can motivate, inspire, and create an enjoyable moment for the children, which can simultaneously be determined to increase learning experiences. A key metric can be the degree to which the children lost track of time when participating in the makerspace activity. Fourthly, the STEM activity was correlated with creativity (r = 0.706). The STEM activity's correlation with creativity suggests that an increase in STEM learning leads to an increased level of creativity, driven by an increased capability to be creative and have innovative thoughts in solving real-life problems. It was also noted that STEM and Environment + Resources (r = 0.655) and STEM and Syringe Rocket Activity (r = 0.849) had a strong positive correlation. Hence, the makerspace activity has adequate resources and facilities that can support STEM learning, and simultaneously, the activities associated with STEM could increase the capability to improve STEM learning and perform makerspace activities. Hence, makerspace can broaden their facilitation of activities that could enhance the experiential skills of the children. Other findings suggested that makerspace activities increased individual creativity, and the facilitation of the environment and resources allowed increased success in the successful learning process among the children.

	1	2	3	4	5	6	7	8	9	10
Family	1									
Experiential	0.710**	1								
Immersion	0.592*	0.831**	1							
Experience	0.368	0.637*	0.636*	1						
STEM	0.655*	0.821**	0.858**	0.612*	1					
Skills	-0.120	-0.102	-0.186	0.252	0.003	1				
Inspiration	0.042	-0.150	-0.226	-0.211	-0.141	0.116	1			
Creativity	0.203	-0.018	-0.113	-0.111	0.106	-0.250	-0.064	1		
Syringe	0.819*	0.905**	0.848**	0.721**	0.920**	0.032	-0.059	0.141	1	
EF	0.604*	0.766**	0.788**	0.562**	0.841**	-0.036	-0.033	-0.111	0.805**	1

Table 35: Correlation Analysis – Adults

In terms of the correlation analysis of the adults (parents), it was found that no correlation existed with skills, inspiration, and creativity factors among the adults. However, there were some forms of correlation found between family learning, experiential learning, immersive learning, task experience, STEM learning, syringe activity, and environment + facilities availability in NSM makerspace. The strongest correlation for family experience was with syringe activity ($r = 0.819$), followed by experiential learning ($r = 0.710$), immersive learning ($r = 0.592$), and finally, EF ($r = 0.604$). The findings of this study suggested that, among adults and parents, family learning had a strong effect on the teaching based on syringe-rocket activity and experiential learning. This implied that, when working together in a family as a group, individuals are subjected to increased experiential learning capability. Secondly, in terms of experiential learning, the significant correlation included the strongest correlation with makerspace activity of syringe-rocket DIY learning ($r = 0.905$), immersive education ($r = 0.831$), and STEM learning ($r = 0.821$). This implies that experiential learning can lead to an increased level of STEM-based learning activity and can also contribute to DIY-based learning activity. Among the parents, it was also noted that immersion, experience, and STEM learning had a strong correlation with each other among the parent/adult. Moreover, it can be noted that compared to the children, the data acquired from the parents indicated that family-based learning contributed to improving STEM learning. Other findings suggested that the availability of environmental resources also contributed to an increased relation with the makerspace activity of the syringe-rocket.

4.3 Outlier Findings in Terms of Age, Gender and Technology

The data acquired from both questionnaires (for children as well as for adults) can shed light on the influence of the Makerspace atmosphere on the learning outcomes, the motivation for DIY activities and the ability of the Syringe Rocket activity to act as a teaching tool. These measures uncover how the sampled participants are divided distribution-wise into different demographic categories such as age, gender, and technology familiarity. Hence, in this section I will explore the main points of these variables, which may point out if there were any outliers or significant tendencies linked to the age, gender, and level of the technology literacy at the time of the space science activity.

In terms of age, the data shows a large majority of the children fell within the age brackets of 9 - 12 years, meaning children in this age group are the most active in Makerspace sessions. For adults the average age group of 40 - 49. The following pattern of age distribution among children and adults implies that the Makerspace activities, especially the Syringe Rocket, are here most attractive and reachable to middle aged provided that they share their time with their children in upper elementary and middle school. This could point to the fact that parents are in a search for activities that are educational but fun as well and will enable single-family participation.

Morevoer, one key factor that is worth taking into consideration is the gender distribution among the child participants. The male participants were in an overall majority (60.9%), which slightly higher than the average child visitor rates to the museum. This gap implies there could be a built-in gender preference in subject interest or within STEM education early on, which the Makerspace aims to counter. In the adult's sample, there were slightly more women (56.5 %). This could be a solution where women spend more time with their children doing such activities. Moreover, women have the sense of responsibility for their children's education and their enrichment.

The study per se did not set out to precisely measure technology literacy levels, however the incorporation of tablets as a user guide in the Syringe Rocket activity indicates that a minimal level of technology involvement was a requirement. Based on the results of this workshop, it can be concluded that both children and adults had the necessary technology literacy or the capacity of quickly adapting to the demanded level of technology savviness in order to join the activity. The many strong connections of experiential learning and STEM learning as well as the great success of the Syringe Rocket activity show that technology was a supportive role in the overall enrichment of the learning experience.

Outliers and Trends

- *Age-Related Outliers*

  In terms of age, there was not any specific outlier described in data. Although the large spectrum of ages of children participants (5 - 20 years) potentially implies that the activities of Makerspace and the Syringe Rocket are also targeted for being widespread, the target audience must be narrowed down. The 9 - 12 years age group involvement could mean that it's the specific age range that responds well to these activates, probably due to the suited age's complicated knowledge and practical tasks.

- *Gender-Based Trends*

  The data itself has not segregated the under performers specifically on the basis of gender but the overall gender distribution highlights an interesting trend distinguishing the gender distribution which was traditionally regarded as male oriented towards the STEM related activities attracting still larger participation from boys. On the one side the appearance of girls (39.1%) is reasonable for Makerspace activities as they look to attract from both genders in a quest to bridge the gender gap in STEM from early stage on.

- *Technology Literacy*

  Given the fact of the successful outcome with the same positive reaction among participants upon Syringe Rocket activity, it is very improbable that there were outliers in technology literacy levels among trial participants at any stage. In any case the technology literacy of individuals with low technology literacy level might have been an issue through detouring and giving instructions through tablets. The lack of specific feedback on this particular issue could mean that there were few such incidences or else they were adequately dealt with by the staff, which certainly shows a creative activity that could be used for students with varied technology literacy levels.

Therefore, it can be noted that The NSM Enjoy Makerspace shows its efficiency in getting different people of different ages and genders all together while doing the Syringe Rocket activity in the programme. The activities draw in children aged 9 - 12 who are still puzzled by the mysteries of the universe, as well as adults aged around 40, and a variety in gender participation that slightly biases to males in children. Technology is an essential factor in the learning process as no difficulty with their technology competence levels has been observed, reported about. This fact sets Makerspace activities apart from the whole with its power to motivate the whole audience get the interest in STEM- related fields and to learn through the experience of experimentation, finding solutions and happy family environment. The future programs may come up with more goal-specific initiatives that aim at involving in the process people who are usually not addressed sufficiently thus finally creating an equal playing field for all of the social groups.

4.4 Results of Qualitative Analysis

4.4.1 Engagement Observation Schedule: Children

This behavioural observation aims to study the participation of attendees in the NSM Enjoy Makerspace activity. I and staff jointly recorded observations before and during the activity, which yielded the following results:

1) **Participation in the activity**

Before the activity:

From observing the behaviour of the participants before the activity, it was found that most children were quite engaged and cooperative with the instructors in answering questions. They talked to their family members about the activities they would be doing that day and were interested in the materials and equipment. They tried to pick up and touch the items prepared on the table by the staff. Additionally, some children were found to be slightly tense and anxious, not daring to speak or express themselves initially before the activity started.

Figure 12: Pre-activity Behaviour observation (showing elements of curiosity, anxiousness, and excitement)

During the activity:

From observing the behaviour of the participants during the activity, it was found that the children began to participate more in the activities, talking more than before the activity started. They cooperated, focused on working on the activities with their families and the instructors, and were very interested in creating their own projects. They followed the instructions while creating their projects and received help from the assistants and their parents until they could successfully complete their own work.

Figure 13: During Activity Behavioural Observation (highly active, participating behaviour noticed)

2) Learning from the activity

Before the activity:

From observing the behaviour of the participants before the activity, it was found that the children were interested in the instructional materials and activity slides. They experimented with assembling various components provided, listened attentively to the instructor's explanations, and were able to respond to questions related to science. It was also observed that while the instructor was explaining, some children were not confident enough to express themselves in discussions or answer questions out loud, often responding quietly and not being very confident in their own answers.

Figure 14: Actively Listening, however demonstrating tense, shyness, lack of confidence.

During the activity:

From observing the behaviour of the participants during the activity, it was found that the children were very interested in the activity and focused on creating their projects. They began to learn by watching their instructors and parents demonstrate how to create the projects and started to follow their parents advice and guidance. After gaining skills and knowledge in using various tools from the instructors, the children became more confident in their creations, attempting to complete their projects independently. When they had questions, they were more willing to ask and discuss their thoughts with the assistants and instructors than they were initially. In addition, it was found that during the activity, the children did not talk much to other groups of friends, tending to be more interested in their own group.

Figure 15: During Activity: confidence build up amongst Childrens, actively participating.

3) Participation in groups

Before the activity:

From observing the behaviour of the participants before the activity, it was found that most children did not yet interact with other groups but were interested in talking and exchanging opinions with family members. They discussed the activities they were about to perform and planned the tasks within their group, along with looking at the creation manuals. In addition, it was found that children began to be interested in and interact with people in their group, sharing and picking up materials and equipment to look at and play with their parents and friends within the group.

During the activity:

From observing the behaviour of the participants during the activity, it was found that the children were quite involved in their groups. They discussed and advised each other on the steps to complete the tasks with their friends and family throughout the activity. They shared materials and tools with others and helped each other in using various tools. During the creation process, parents allowed children to try using the tools themselves. If the children encountered problems, their parents were there to help and provide guidance to find solutions to the issues encountered during the creation process together.

Figure 16: Active Group Participation Observed

4) Interaction with the environment and resources

Before the activity:

From observing the behaviour of the participants before the activity, it was found that when children entered the activity area, they would sit and observe the atmosphere and surroundings in the Enjoy Makerspace room. After that, they would start to be interested in the materials and equipment on the table in front of them, such as picking up the tools to ask their parents, picking up the Syringe to look at, and opening the activity manual. When the instructor began to introduce themselves and explain the activities to be carried out that day, the children appeared excited, listened attentively, and showed interest in the activity, participating in answering questions with the instructor.

Figure 17: Pre-Group environment interaction (indicating curiosity, and awaiting instructions and guidelines)

During the activity:

From observing the behaviour of the participants during the activity, it was found that the children interacted with the environment in the Enjoy Makerspace room. They learned to choose materials and how to use the equipment, such as learning how to use a glue gun, a drill press, and a screwdriver. Additionally, the children studied the manual before starting the hands-on work and cooperated well with listening to the instructor and the assistant instructor during the Syringe Rocket crafting activity.

Figure 18: Post-Activity Interaction (indicating more comprehension with environment and resources available)

5) Expression and conversation

Before the activity:

From observing the behaviour of the participants before the activity, it was found that most children had bright eyes and were excited about the upcoming activities. Children were interested in the equipment placed in front of them, discussing and explaining the work steps together with their family members. They listened attentively to the explanations from the instructor and tried to understand what the instructor was communicating. In addition, it was found that some children were also interested in the activities but were not very confident in speaking or expressing their opinions. Instead, they used body language to answer questions, such as nodding or frowning. Although, it must be noted that due to the times of pandemic, all families were required to wear a mask, which made it quite difficult to fully comprehend the expressions.

Figure 19: Pre-activity Expressions

During the activity:

From observing the behaviour of the participants during the activity, it was found that the children expressed their enjoyment through their happy and excited faces as theytried creating the Syringe Rocket. In the process of using the tools, most children wanted to try using the tools themselves. When they succeeded, they seemed to enjoy it and had a bright smile on their faces, excited that they could try something they had never done before, and they started to gain the confidence to answer questions from the instructor. Only a small portion of the children appeared to be quiet and did not clearly show whether they liked or disliked the activity.

Figure 20: During Activity Expression

(a sense of confusion, excitement, and happiness can be noted)

Summary of Observations: Children

From the observations, it was found that before starting the activity, most participants cooperated with the instructor, answered questions, and talked with their family members about the action. They showed interest in instructional materials and equipment, picked up objects that were placed around, observed tools and the atmosphere in the Enjoy Makerspace room, and were excited to participate in the upcoming activity. The children who participated in the activity experimented with assembling various components, listened attentively to the instructor's explanations, and responded to scientific questions. Most of them did not interact with other groups. However, they were interested in discussing and exchanging ideas with their family members. They talked about the upcoming activities and planned them within the group while looking at the invention manual.

Moreover, some children were found to be slightly anxious, not daring to speak or express themselves at first before starting the activity. This is very common among the child participants at NSM Enjoy Makerspace activities, in which children are sometimes grouped with strangers and have not become comfortable with others. The NSM Enjoy Makerspace staff members do have approaches to address shyness among visitors. However, our main strategy is to allow visitors to come to their level of comfort through engagement in the activity rather than trying to force outward expressions of interest. This approach is taken because we recognise that children have different learning dispositions and practices, with some becoming highly visibly engaged and others having less visible (but no less deep) interest. Moreover, it is essential to acknowledge that some youngsters may need more time to verbalise or express their ideas before engaging in the given task. This phenomenon is often seen among youngsters who engage in NSM Enjoy Makerspace programmes. The individuals in question may find themselves in the company of strange acquaintances, resulting in a lack of mutual comfort and familiarity. The NSM Enjoy Makerspace team uses a number of strategies to make shy customers' visits more pleasant. The main approach applied is through the help provided to visitors to uncover their comfort level naturally by being active in a certain activity, instead of forcing visitor's enthusiasm. This technique has been chosen in view of the realization of various learning styles of little children. Some people express their interest openly, while others may have a subtle but equally profound curiosity. To build a positive rapport with participants immediately, the staff person must have the required skills to identify and accommodate individuals' differences.

The Syringe Rocket activity reflected that participants were hands-on, building a closer bond with the family and instructor, as partners. Their experimental spirit was noticeable as they tried to put their projects together, working with the instructions provided by themselves. The kids learned by watching their teachers and parents, copying what they did. On obtaining the knowledge and skills in the use of the tools from the instructor's children started to work more confidently in their experiments. When such challenges were experienced, their parents came to the rescue where they offered advice on how to maneuver around the obstacles. Children also interacted with the ambiance of the Enjoy Makerspace room and learned what materials to choose and how to use glue guns, drills or pliers. They consulted the manual for the Syringe Rocket activity before beginning the experiment. The children were very spirited about the Syringe Rocket experiment and gladly used the tools. The accomplished, enlivened faces of them suddenly became happy faces jumping for joy. They were excited about having learned something new and now were less timid when replying to the questions of the teacher.

Key themes identified:

The following figure identifies the key themes that were noted before and during the activities:

Before Activity

- Engaged and cooperative with instructors
- Interested in materials and equipment
- Excited about the activity
- Tense and anxious
- Interested in learning and asking questions
- Shy and lack of confidence in expressing themselves

- Interacted with family members
- Observed and studied the environment.

During the activity:

- Highly active and participated in the activities
- Interested in creating their own projects
- Followed instructions and received help from instructors and parents
- More confident in their creations
- Willing to ask and discuss questions with instructors and assistants
- Involved in their own group
- Interacted with the environment and learned to choose materials and use tools
- Expressed enjoyment through their happy and excited faces
- Gained confidence in answering questions from instructors

Figure 21: Before Activity Common Themes

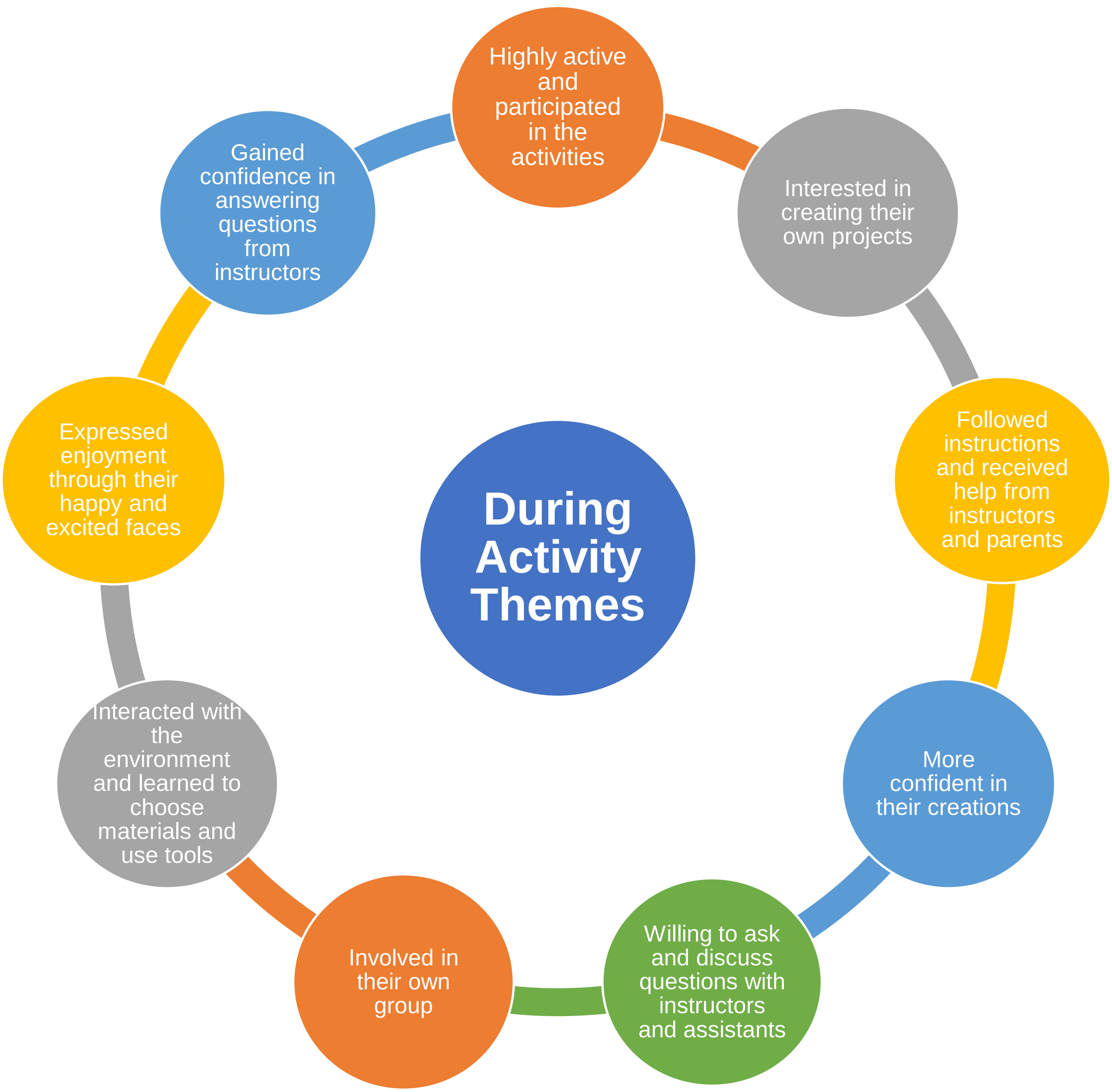

Figure 22: During Activity Common Themes

4.4.2 Engagement Observation Schedule: Adults

The objective of this observational research is to investigate participations of the members in the NSM Enjoy Makerspace activity. The researcher and the group made notes of the observation prior to, during and the activity. The results of the observation are as follows:

1) Participation in the activity

Before the activity

From the observation, it was found that the participants were interested in the tools in the Makerspace and paid attention to the lecturer explaining the steps of creating the Syringe Rocket project. The lecturer also encouraged the children to ask questions and explained the steps of creating the project to help them understand. Prior to engaging in the observation-based analysis, it can be noted that, some of the families and the children had started engaging with the tools prior to being introduced by the lecturer or the teacher' s during the activity. Some of the children also had started engaging with the activity by themselves, prior to learning about the project.

During the activity

The mothers were interested in making toys and the fathers monitored the children during the activity. Some families participated in the project by having the children experiment and the fathers helped with some steps. Some mothers also made their own projects and let their children participate and learn by doing. From the observation, it can be noted that, parents were motivated to help their children in the project, as the parent's had helped the children in developing the Syringe Rocket project. Furthermore, the parents had guided and advised the children thoroughly when the children were attempting to follow the guide, across different steps and helping to address challenges associated with the use of the tools.

2) Learning from Activities

Before doing the activity

From observing, parents have noticed the way to play Syringe Rocket when the facilitator explains the steps. Parents are interested in the activity and pay attention to the facilitator's explanation of the steps, asking questions, and letting the children express their opinions. The facilitator will also answer the children's questions and provide more explanations to help them understand better. The goal is to develop children's problem-solving, experimentation and innovation skills by doing the activity. Some families just sit and listen to the facilitator's lecture without any interaction. They may take photos of the children during the activity.

During the activity

From observing, parents have shown interest in the Syringe Rocket activity and have participated together with their children. They ask questions, answer and express opinions throughout the activity. The facilitator explains and demonstrates the materials and tools that will be used in the activity to the children and lets them see the examples. During the activity, the children use the examples as a reference. The facilitator also talks and advises on safety precautions when using tools and helps the children handle the tools. The children work on the activity until they successfully complete it.

3) Participating in the group

Before the activity

From observation, the participants have conversations with each other during the activity, from materials to equipment. They examine the materials before starting, try assembling parts before starting, explain the steps, encourage the children to listen and help each other in the family. The instructor explains the steps and encourages the children to read the manual while making the project. Some fathers help from a distance and allow the children to do it themselves, and occasionally provide additional explanations if the children cannot do it. Some mothers also make their own projects, and some mothers do not participate in the activities as much. They will take videos and take pictures while the children are making their projects by themselves. The extent of variation in parental behaviour, and the fact that parents of both genders were willing to let children's complete activities themselves, was interesting.

During the activity

From observation, parents help each other in the family in making the project. They have conversations with the assistant instructor about the activity, explain the steps of the play, and talk to the children while doing the activity. They explain the use of tools and equipment, provide materials and equipment to the children, and some steps of the project require fathers to help solve problems, help hold the base of the project, and make it easier to attach the glue. They give advice on the decoration steps of the project, and some families allow the children to do it themselves. They tell them how to use the tools and how to make the project. Some mothers also help to turn the base of the project, help hold the base, and use the glue gun to hold the base of the project. They also have conversations with other mothers in the group about the development of their children, which was interesting as it was a type of social interaction that was not observed so much between fathers.

4) Involvement with the Environment and Resources

Before the activity

From observation, parents are interested in the tools used in the creation of toys. They want their children to try using these tools and have fun in the Makerspace environment. Before children start creating, the parents and the guide will explain the materials and teach them how to create. They will also provide the manual for the activity and watch the demonstrations from the guides. Some mothers will sit quietly and listen to the guide's lecture, letting their children do the activity on their own.

During the activity

From observation, participants explain and suggest the use of tools and equipment for the children to better understand the creation process. They work together with the guides and follow their instructions. They encourage the children to listen and follow the steps shown by the guides. They suggest reading the manual during the activity and choosing the appropriate materials. Some families bring a Syringe Rocket as an example before they start creating. The parents initially let their children try to create on their own and let them use the tools. The mothers help their children with the decoration and using tools such as pliers and foam cutting. They design the project together with their children until they are successful in creating their own project.

5) Expression and conversation

Before the activity

From observing, the participants in the activity have ongoing conversations throughout the activity, encouraging the children. There is interaction with the activity, with questions and answers, excitement about creating the play, conversations within the family, explanations of the components of the workpiece, and mothers are happy that their children are able to experience the Syringe Rocket activity together. Fathers take photos of the family while doing the activity, mothers provide guidance and let the children watch the example before doing it.

During the activity

From observing, the participants in the activity have asked questions and talked about the explanation of the methods of creating and using tools, encouraging the children to participate in the activity. They ask questions, encourage them to think and answer, guide the use of tools, encourage them to think and try, and ask them questions throughout the time they are creating the play. Some families are excited about decorating the rocket, and they encourage the younger ones who are not confident in doing some steps, but they will let the children do it themselves, choose materials and plan on their own.

Summary Observation: For adults

From observation, before the activity, the participants actively participated in the Syringe Rocket activity by observing different tools and paying attention to the presenter's instructions on the steps of creating the project. They asked questions and encouraged the children to ask the presenter questions, provide explanations, understand the actions of completing the project, and study the manual before starting the activity. There was learning from the activity, observing the method of play, asking questions, and allowing children to express their opinions. The adults provided additional explanations to help the children understand more, wanting the children to develop their creativity skills, experimentation, and problem-solving skills. There was participation in the group, conversation during the activity, trying out the components before starting the project, and explaining the steps of the project to the children. Some families had fathers who helped from a distance and allowed the children to do it themselves, while others provided additional explanations. There was learning about materials and tools and cooperation with the presenter, allowing the children to try using the tools and experimenting with the components before starting the project. The adults studied the manual and encouraged interaction with the activity, asking and answering questions and explaining the parts of the project throughout the activity. Encouraging children to have a relationship with the activity and facilitating communication and expression.

During the activity, it was observed that the behaviour of the participants during the activity was that the parents participated in the action and were able to assemble the Syringe Rocket successfully. They helped, provided guidance, and instructed on the steps of using tools and taking care of the children while completing the project. There was learning during the activity, hands-on assembling with the children, and asking and expressing opinions during the assembly process. The use of materials and tools was explained, and there was participation within the group, where the parents helped in the family's assembly of the project. There was communication with the teaching assistants about the activity and explaining the steps of the game. There was communication with the children during the activity, demonstrating the use of the saw and other tools. There was interaction with the environment within the Makerspace, encouraging the children to listen and follow the steps of the teaching assistants. The activity manual was recommended for study during the assembly of the project, and the actions of assembly and selection of appropriate materials were chosen. Questions were asked, and the method of assembly and use of tools were explained to the children throughout the time. Encouragement was given for the children to participate in the activity by asking questions, encouraging them to think and respond, and suggesting ways to use the tools.

Key Themes Identified:

Before Activities:

- Interest in tools and materials
- Paying attention to the lecturer’s explanations
- Encouraging children to ask questions and participate
- Listening to the introduction of tools and steps
- Experimenting and taking photos/videos of the activity
- Conversations with other participants
- Examining materials and assembling parts before starting

During Activities:

- Actively assisting and guiding children in the project
- Providing guidance and advice on using tools
- Engaging in the activity with enthusiasm and interest
- Asking questions, answering, and expressing opinions
- Encouraging children to follow instructions and safety precautions
- Helping children handle tools and complete the project
- Collaborating with other family members in the activity
- Conversing with assistant instructors and other parents
- Assisting children in decoration and use of tools
- Encouraging children to think, answer questions, and solve problems
- Documenting the activity through photos and videos

Figure 23: Before Activity Themes

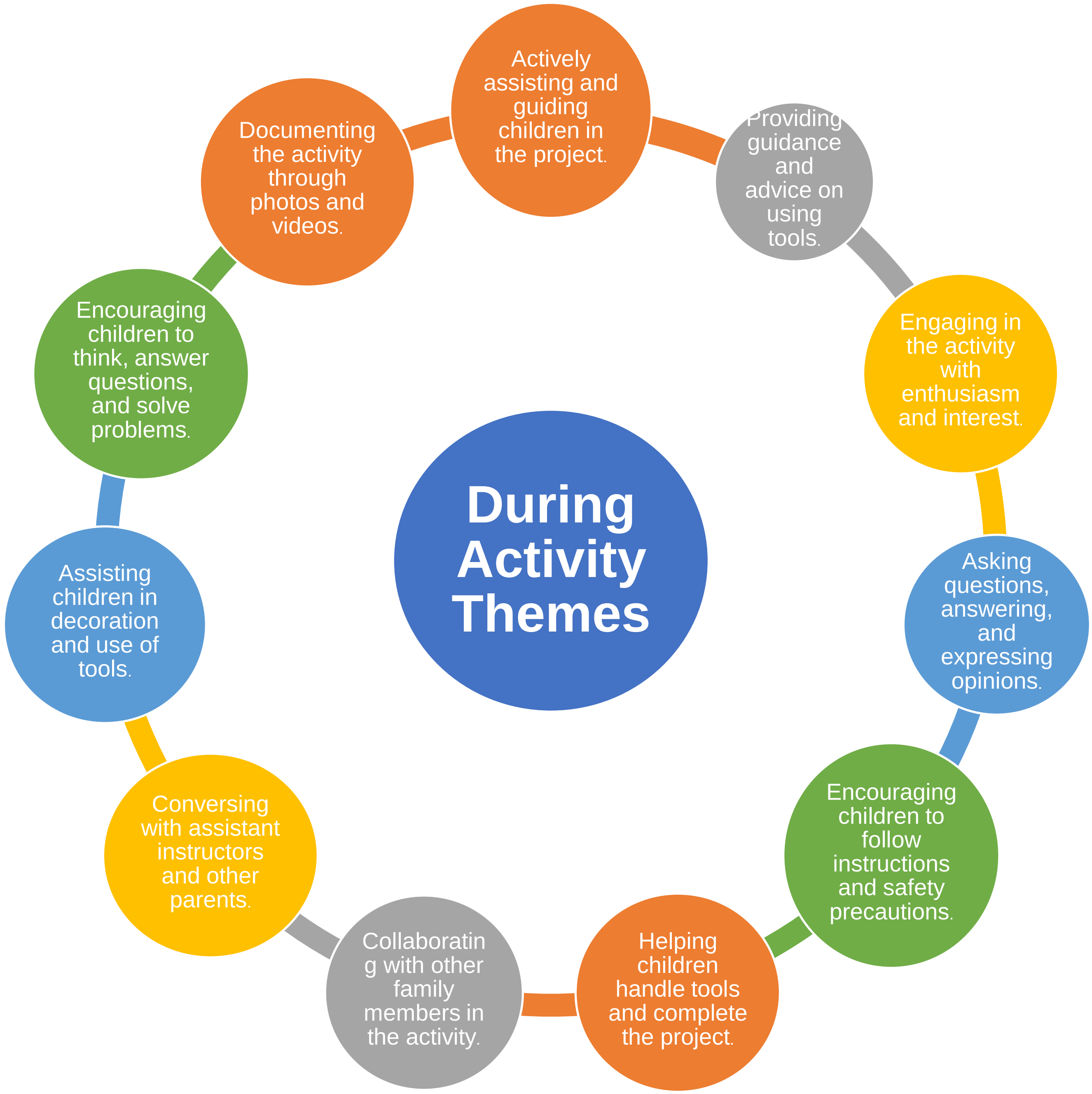

Figure 24: During Activity Common Themes

Based on both of the findings, the broader themes identified in the Engagement Observation Schedule for Adults and Children highlight the significance of a supportive and collaborative learning environment. For adults, the themes “Active Engagement and

Supportive Learning Environment” and “Collaborative Learning and Nurturing Creativity” emphasise the role of parents and instructors in fostering an atmosphere that promotes curiosity and exploration, while also guiding children in their learning journey. For children, the themes “Curiosity and Initial Exploration” and “Empowerment, Skill Development, and Creative Expression” capture the essence of their experience as they transition from initial curiosity and exploration to gaining confidence and developing valuable skills through hands-on activities. Each of these associated themes are developed over the framework that contributes to stimulating and nurturing environment where both adults and children can engage, learn, and grow together.

Based on this, a set of broader themes can be identified in this study for adults and children as indicated below:

Broader Theme for Adults:

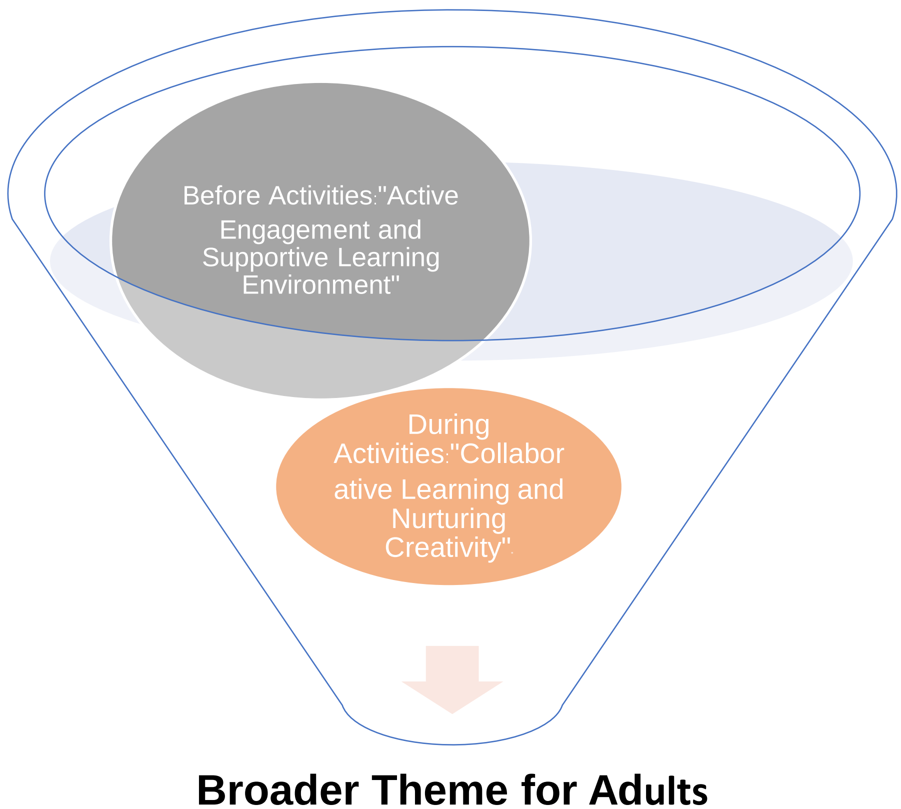

Figure 25: Broader themes for adults

Before Activities:

- “Active Engagement and Supportive Learning Environment”

During Activities:

- “Collaborative Learning and Nurturing Creativity”

Broader Theme for Children:

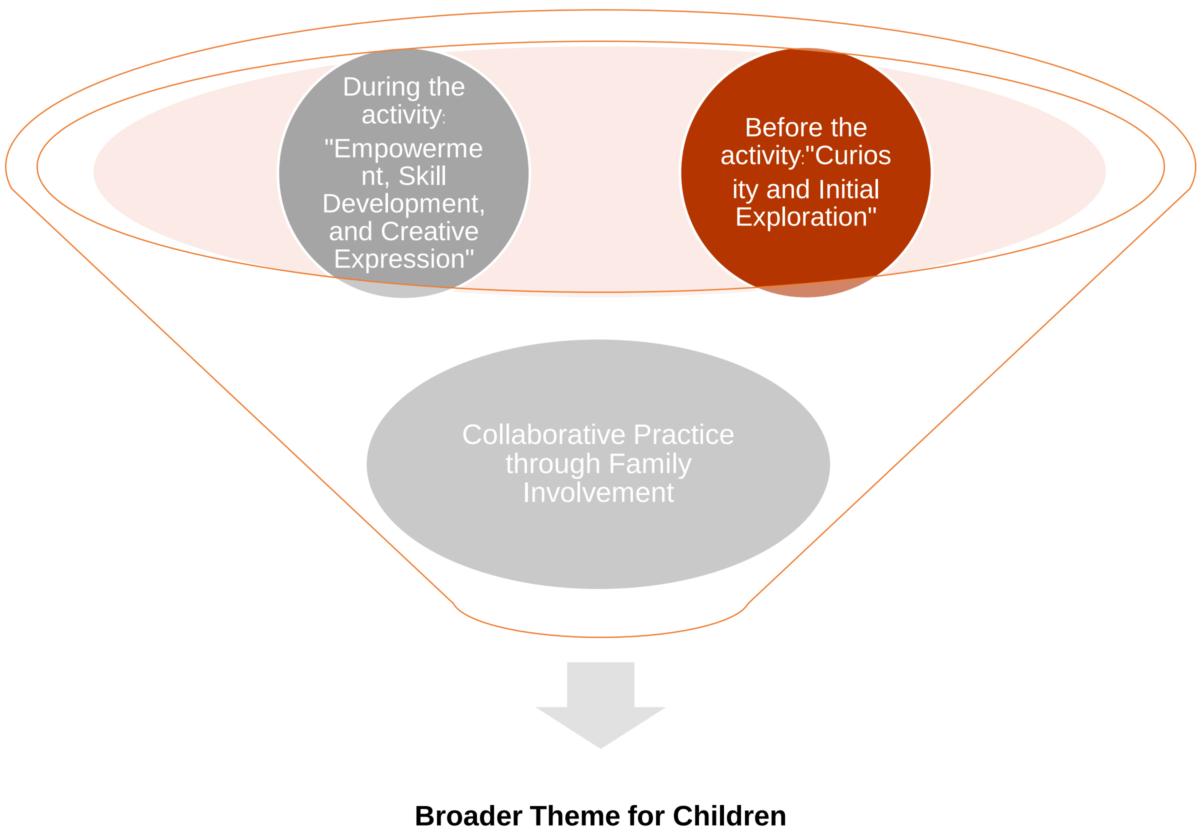

Figure 26: Broader Theme for Children

Before the activity:

- “Curiosity and Initial Exploration”

During the activity:

- "Empowerment, Skill Development, and Creative Expression"

4.4.3 STEM Learning Observation Model: For Children

Observations on STEM learning behaviour for children allow for the summarisation of learning activities. The research team and staff worked together to observe and record during the Syringe Rocket activity at Enjoy Makerspace. Observations and informal interviews, along with the researcher's (my self-observation) own observations, were then analysed to identify key learning behaviours. The observed learning behaviours are as follows:

1) Learning in science (such as understanding the scientific principles of Syringe Rocket, asking or answering questions, etc.)

The conduct of the activity allowed all participants to learn about the scientific principles that were associated with the development of a Syringe Rocket, with the lecturer explaining the key steps associated with the development and incorporation of scientific elements associated with developing a pressurised rocket. The children, as a participant in the study, were capable of experiencing the syringe-rocket concept in a hands-on manner. Furthermore, it was duly observed that when the lecturer explained the syringe pocket activity, the children had high focus and attention, including a sense of curiosity that triggered a significant effect on the behaviour of the children. In an example, it can be noted that one of the children was captivated and interested in understanding the changes in the size of the syringe tube, or if and whether the syringe base could be changed - and its eventual outcome and effect on the syringe-rocket.

In addition to that, the majority of the children participating in the activity had basic and foundational knowledge of science, which was depicted by their capability to answer questions associated with the science behind a pressurised rocket. However, younger children grouped in the "others" segment in the age group - were also aided by their parents when attempting to answer some questions during the activity. During the activity, all children participated in the construction of the project. Some children even made their rockets and tested how far they could launch them. At the end of the activity, all participants summarised what they learned from the activity.

2) Learning in technology (such as having skills in crafting, selecting suitable materials, and understanding the techniques in crafting Syringe Rocket or others)

Participants in the activity were able to use their design skills to craft Syringe Rocket, particularly in the process of designing the rocket and wooden base for the Syringe tube. They were able to use their imagination and creativity in designing their rockets using the materials and equipment provided.

Observations revealed that during the rocket design process, the children used their creativity and imagination to design and decorate their rockets, with most of them having the necessary skills to select suitable materials for the Syringe Rocket activity. They were able to choose materials that were appropriate for the rocket decoration process. Some children drafted their designs before constructing the rockets and sought advice from their parents and the lecturers or assistants on how to use materials to make their rockets more beautiful and fly farther. Some younger children had assistance from the lecturers in developing their crafting skills.

3) Learning in engineering (such as being able to construct and use tools efficiently, solve problems when Syringe Rocket is not working, and others)

Observations showed that younger children who participated in the activity below the age requirement needed assistance from the lecturers in using the tools efficiently. However, when they began working with the tools, they were able to use them efficiently, as some families had already engaged in crafting activities that made the children familiar with tools. The tools provided made crafting more convenient, such as glue guns, clamps, drills, and scissors.

4) Learning in Mathematics

Observing the learning behaviours of children participating in the Syringe Rocket STEM activity, it was found that they possessed basic knowledge of mathematics related to measurement and estimation of the length of materials or devices using visual perception. Some modified the activity by using a ruler to draw straight lines. In contrast, others used trial and error by fitting the parts together to match their design, with help from family members. In addition to that, the researcher observed that during the activities - some problems arose, particularly associated with estimating the point to drill on a piece of wood, using foam to measure for decoration, and measuring the weight of the rocket to make it lighter. These issues were, however, associated with using mathematical skills to solve them. The issues led the researcher to observe that the majority of the children that participated in the makerspace activity of Syringe Rocket activity had minimal skills associated with being an inventor.

Similarly, it can be stated that, observing the learning process of the children, particularly in terms of the science, technology, engineering, and mathematics (STEM) learning experience, it was observed that the children lacked skills associated with the invention, material selection, and technical understanding. Furthermore, the observation also revealed that the children had a limited level of problem-solving skills and required contribution from their parents. For instance, the basic knowledge that the children were associated with includes the knowledge in terms of air pressures - particularly in association with the Syringe Rocket. Moreover, it can be noted that the complicated features like the utilisation of drills, jigsaw tools, and hot glue guns have limited knowledge and, therefore, require guidance from their parents. Finally, the observation also noted that the children enjoyed decoration and were able to apply their mathematical skills to measure and estimate the length and weight of materials for decoration purposes.

4.4.4 STEM Learning Observation Model: For Adults

1) Learning in Science (e.g., understanding the scientific principles of Syringe Rocket, asking or answering questions, etc.)

In the activity, all participants will learn about the scientific principles related to the invention of the Syringe Rocket, with the instructor providing explanations and teaching the steps of the invention while incorporating scientific content. This allows participants to learn scientific principles through hands-on invention and practice science skills simultaneously. From observation, it was found that when the instructor explained the principles of air pressure in launching the Syringe Rocket, some parents already had adequate knowledge and skills in understanding air pressure and could answer children's questions or address their doubts. In addition, some parents could provide supplementary knowledge beyond the instructor's explanations, such as principles related to the Syringe Rocket's projectile motion.

2) Learning in Technology (e.g., having skills in inventing, choosing appropriate materials, and understanding techniques in creating the Syringe Rocket or other inventions)

Participants will use design skills in the activity's design and decoration steps for their own rocket and wooden base for placing the Syringe. Parents can design the project and base it according to their imagination, using materials and tools prepared in advance. From observation, it was found that when it came to the decoration step, parents allowed children to use their creativity and imagination to decorate their rockets freely. Once the children completed the rocket structure design, parents provided advice and guidance to help the children. Most parents already had skills in inventing and understanding material selection. They were able to advise and provide techniques for children in choosing decoration materials, such as selecting the weight of foam sheets for rocket decoration, designing rocket wings, and choosing lightweight decorative materials.

3) Learning engineering skills (such as being able to invent and use tools proficiently to troubleshoot when the Syringe Rocket does not work)

In the Syringe Rocket invention activity, various tools are available for participants to use, including general tools such as scissors and cutters, as well as specialised tools like glue guns, screwdrivers, and drill presses, with assistants on hand to help with equipment usage or to assist with tasks. From observation, the parents were able to use general tools proficiently without any problems. In terms of specialised tools, all parents could use glue guns and screwdrivers well and could teach their children how to use them. However, some parents had never used a drill press before and needed help from the assistants to learn how to use it and gain confidence in using such specialised tools.

Learning mathematical skills (such as being able to use tools for measurement, estimation, comparison, and applying problem-solving methods in mathematics or otherwise)

In the activity, participants learn to invent by using mathematical skills in measurement, calculation, estimation, or applying mathematical skills to help solve problems during the invention process. From observation, it was found that parents could effectively use mathematical skills during the activity, such as planning and estimating before drilling holes in the wood with their children, ensuring accurate drilling. In the decoration process, parents advised their children to calculate the appropriate weight for the rocket to achieve the best performance and distance.

Summary of research findings on the observation of adult learning behaviour in Syringe Rocket STEM activities

From observing the learning behaviour through the Syringe Rocket activity, it was found that most of the participating parents had skills in being makers. They started by observing various processes, including learning science (understanding scientific principles), technology learning (invention skills, material selection, and understanding techniques), engineering learning (using tools in inventing and problem-solving), and mathematics learning (using tools for measuring, estimating, and comparing). These processes form the basis of being an inventor. Parents applied their knowledge and skills in inventing for this activity. The apparent prevalence of making skills among parents does raise the question of whether parents who do not have confidence in these skills avoid bringing their children to the Makerspace or do not engage with their children's experience within the Makerspace. As older children are free to visit the NSM Enjoy Makerspace on their own and do not have to be accompanied by parents, some children of parents who are less interested in or confident in the making may do so. It is also possible that a disproportionate number of parents who were not confident in this area turned down participation. This is something that needs to be investigated further.

Through observation, it was found that parents had scientific knowledge, material selection skills, design skills, estimation and comparison abilities, and basic and advanced tool usage skills. They were able to explain academic principles and provide assistance in using tools to their children.

4.5 The Motivation and Learning Outcome Interview (MLOI)

From participating in the “Syringe Rocket” activity at Enjoy Maker Space @ Science Museum, researchers interviewed participants about their motivation and learning outcomes from the activity. Qualitative findings associated with interviews are presented in the following table below, which includes a review of the interview excerpts, and this also involves coding and thematically grouping the key analysis. The following table below shows the results of the motivation interview:

Topic	Results
Were you interested in participating in the Syringe Rocket activity? Why were you interested?	• Yes, I was interested because I could do it myself and had friends around. • I felt that it was an activity that I could have fun with. • I brought my child to do it and they learned scientific principles and how to use tools. • I was interested because I wanted my child to learn something outside of textbooks, see something real, and do something practical. • The activity looked interesting and allowed the child to try it out, use creative thinking, and enhance their own potential. • I think this activity allowed the child to actually make something and remember it more. • I wanted to make a toy and when I got to do it, I found it a lot of fun. • I wanted the child to learn about science, and this activity could be a tool for learning. • I was interested in doing a fun activity and wanted to try it out. • The child already liked making things, so I thought this activity would improve their skills in making things.

Topic	Results
	• The child was interested in this activity and wanted to try making a rocket. • I was interested because the activity integrated well with scientific knowledge. • I thought it was a fun activity to play. • I was interested in participating because the activity looked fun and interesting. • I was interested in participating because the activity looked easy to do and fun. • The child enjoyed it a lot and wanted to do the Syringe Rocket activity again because they had done it before. • I was interested in participating because it taught basic crafting skills for families and inserted science skills.
Can everyone successfully complete the Syringe Rocket activity? Were there any obstacles encountered during the activity?	• Yes, it was successful with guidance from instructors and activity manuals. • Success was achieved through family assistance. • Initially, I thought it couldn’t be done, but we succeeded. • It was successful because everyone helped plan and consult with each other. • The activity was successful, and everyone helped each other out, and children made suggestions on how to make the rocket heads. • It was successful because everyone worked together, learned from instructors, assistants, and manuals. • It was successful, and the final product was better than expected. Initially, the weight of the rocket was too heavy, and it didn’t shoot far, so the child tried adjusting the weight until it shot far. • It was successful as intended, and we need to thank the assistants who provided guidance and advice.

Topic	Results
	• It was successful because we listened to the instructors explanations and family members provided guidance on how to use tools correctly. • Everyone was able to successfully complete the activity, and there was consulting for crafting. • It was successful because everyone worked together. • It was successful because the equipment was ready, and the guidance from the instructor was good, making the activity easy to understand. • It was successful, and the child did the activity independently at every step, with the mother helping to hold equipment in some steps. • It was successful, and it was especially suitable for supporting family activities.
Did the Syringe Rocket activity increase your confidence in becoming a maker? How did it affect your confidence?	• Increases confidence, as it provides benefits and allows children to create on their own. • Increased confidence in being able to do it themselves. • Increased confidence in being a maker. • Increased confidence because they had never created a toy or piece of work before. • Increased confidence because the activity was initially thought to be difficult but turned out to be easier than expected. • Increased confidence to make other things and other pieces of work. • When the child knows what the problem with the rocket is, they try to solve it themselves. This makes them more confident in being a maker. • Increased confidence because the end result was good. • Builds confidence in using workshop tools for making.

Topic	Results
	• Increased confidence because they have practiced and learned to use unfamiliar tools. • Increased confidence because they were able to use appropriate tools for the activity.

Table 36: Results of Motivation Interview for Syringe Rocket Activity

The table above offers a multi-faceted perspective on children's motivation and their experiences participating in the Syringe Rocket activity. From the first category, it is evident that the activity stirred enthusiasm among participants due to various factors, such as the opportunity to perform hands-on work, the companionship of friends, the chance to learn scientific principles, the appeal of learning beyond textbooks, and the enhancement of creative thinking and practical skills. Moreover, for many people, it was fun, looked interesting and was perceived as the opportunity for formation of memory and skills. The physical link to scientific information and belief that the task was simple and enjoyable also influenced the participants response rate.

The overall feedback about the ability of the participants to complete the Syringe Rocket activity and possible obstacles encountered was mostly positive. Success was achieved by most of the respondents due to assistance of instructors and activity manuals, family support, collective planning, advice and teamwork, many noted. Although initially the rocket being too heavy was one of the challenges, the hands-on problem-solving approach lead to the improvement of the final result, which was considered an achievement.

The Syringe Rocket activity affects the forth outcome which is confidence to become a maker positively. Participants stated that the activity resulted in improvement of self-efficacy towards the creation, problem-solving, and usage of workshop devices. Overcoming what was perceived as initial difficulty, successful creation of a concrete piece of work, and using strange tools nicely went with their raised confidence levels. It means that the Syringe Rocket activity had a critical impact on developing a maker's mentality, stimulating the problem-solving skills and increasing self-assurance of the children involved.

Hence, the Syringe Rocket activity has given these children a platform that was both enjoyable and informative, in effect creating a learning environment. Therefore, the majority of the participants stating DIY nature of the activity as one of the main reasons of their interest, makes it obvious that hands-on approach promoted involvement and achievement. It is a proof of the power of an experiential learning and influence of the motivation on children, that practicality is a crucial factor in education. Also in this situation, the spirit of cooperation and teamwork was very evident in the process of overcoming obstacles. The reports of the children show that collaborative problem-solving, be it with the family, the peers or the monitors, figured much in the realization of their projects. This shows that the Syringe Rocket activity promotes teamwork and improves the collaboration capabilities of children, crucial life skills.

Based on the above, the confidence in the children further cements the tendency of various activities including Syringe Rocket to make the children self-assured and competent learners. The achievement of a hard project, with the use of unknown tools and techniques, to these children, is an empowerment. In this way, the Syringe Rocket activity promoted, besides the acquisition of the technical knowledge, a great self-confidence and determination in the children as potential creators and solvers of problems.

Having said that, the feedback that was positive about the Syringe Rocket activity shows that it is an effective way of active learning, promotes hands-on learning, teamwork, and self-esteem among children.. These are all critical aspects of child development, and their cultivation through enjoyable activities such as the Syringe Rocket can have far-reaching benefits for these young learners.

Next, the following table demonstrates the science-related learning outcome from the interviews: The question emphasis extends beyond the maker’s talents, including a wider range of abilities and knowledge gain. Individuals may articulate their learning goals with it, which could go beyond conventional maker skills. This inclusiveness guarantees a thorough comprehension of participants learning objectives.

Topic	**Results**
How did the Syringe Rocket activity help you understand the principle of pressure in science?	• Better understanding of the principles of science, including the working principles of rockets. • Increased understanding of science principles because my dad already understood the concept of air pressure, and the larger syringe allowed the rocket to go farther. • Understanding the working principles of Syringe Rocket, which is a rocket body that can be shot out by the air pressure inside the rocket or syringe. • Increased understanding of how rockets move using air pressure. • Better understanding due to a well-explained lecture by the science teacher that was easy to understand. • Improved understanding of various science principles such as pressure, dynamics, and projectile motion. • Increased understanding that such a small syringe could not make the rocket go as far as it did. • Improved understanding of the principles of pressure through practical experimentation with rockets. • Helped visualise and understand science principles more clearly. • Increased understanding and appreciation of learning science through this type of activity. • Improved understanding of the use of pressure through the activity, which was evident and easy to observe.
In which areas did the Syringe Rocket activity help you	• Developed skills in using woodworking tools such as drills and glue guns, and improved focus and concentration. • Practiced skills in using tools for crafting and fabrication.

Topic	Results
develop new skills?	• Used a drill for the first time and learned design skills. • Developed skills in using tools and became interested in learning more about different types of tools. • Tried drilling holes with a drill for the first time and found it fun and not as scary as expected. • Used tools such as a saw, drill, and glue gun for woodworking. • Helped develop skills in using tools for children who had never used certain tools before, such as drills and clamps. • Improved skills in using a drill press for woodworking. • Learned to use hand tools, knots, and a glue gun for making wooden crafts.
What new skills or knowledge do you want to learn or develop from participating in the Syringe Rocket activity?	• Learned about innovation, repairing and creating things at home. • Interested in learning about renewable energy such as solar energy, oxygen, clean energy to reduce pollution. • Want to develop new skills such as doing something useful. • Created a car sunshade, sunshade, and equipment that can convert energy for use, such as solar cells. • Want more new activities to develop various scientific skills for children. • Want to learn more about science and engineering skills. • Interested in technology for treating wastewater using pressure or water. • Want to learn more about science toys with more advanced mechanisms. • Want to have more fun and exciting activities like this and try new inventions such as creating light sticks or something related to light. • Want to learn more about rocket shapes.

Topic	Results
	• Want to learn about making walking robots. • Interested in using air pressure to drive rockets. • Want to encourage children to learn more about DIY science projects because it was previously thought that children might get bored, but the experience of attending a class for creating things has shown that all children are eager to learn and create.
Did the Syringe Rocket activity inspire you to be creative? If so, how?	• Developed skills in toy decoration and designing various toys. • Developed skills in science and art of decoration. • Helped in enhancing creative thinking. • Used imagination in toy designing. • In terms of the rocket decoration process, it fostered creative thinking. • Had creative ideas in rocket head design. • Helped in developing creative ideas in rocket shape designing. • Helped in developing creative ideas on how to make rockets go farthest. • Initially didn't want to decorate anything, but after starting the activity, became interested in trying to decorate the workpiece. • Helped in developing further creative thinking in daily life. • Fosters creative thinking and utilises skills in designing. • Helped in developing skills in design.

Table 37 : Science related learning outcome from the interviews

Table 30 provides an overview of the perceived learning outcomes of the Syringe Rocket activity, particularly focusing on understanding scientific principles, skill development, future learning interests, and creativity.

To begin with the fact that the Syringe Rocket activity was successful in improving participants' understanding the scientific principles, pressure in particular is observed. After the children carried out physical experimentation on the rockets, the participants were able to comprehend how a pressurised rocket operates and learned the fundamental principles of pressure dynamics. The interview also revealed that the respondents perceived the Syringe Rocket activity as helping them better understand science in its basic principle of pressure to complicated principles of using projectile motion driven by pressure.

In the second place, the Syringe Rocket activity also helped the acquisition of the new practical skills related to the DIY project, especially with arts and crafts. At the Syringe Rocket activity, the participants used different materials, like woodwork and glue guns to build the rockets. So, the skill acquired through the project was the ability to participate in creation activities.

In addition, the activity also raised the curiosity and enthusiasm among the participants. It was observed that the participant's curiosity and interest had woken up in the framework of STEM learning – related to science and technology especially. This increased the involvement in practical activities that can trigger curiosity to learn and expand the horizons in the Syringe Rocket activities. Finally, the activity was also seen as a catalyst for developing creativity. This was further affirmed in the findings proposed in the correlation analysis presented in the quantitative findings section of this study. The findings confirmed that the exposure to the rocket shape and decoration encouraged creative thinking skills and design skills, which could further inspire them to apply creativity in real-life scenarios.

There were some interesting aspects of the questions in relation to new skills and desired knowledge. Participants were very likely to identify new skills, such as woodworking and tool use skills, which are commonly taught in secondary curricula. This was also true of the knowledge learned, for example, the principles of air pressure on which the Syringe Rocket activity was based. This suggests that the makerspace activities are pre-developing knowledge that students will learn formally later. This could provide an advantage for students who engage in these activities early.

Furthermore, the activity sparked interest in areas beyond the scope of the makerspace activities, such as engaging with solar energy development. This is in addition to interest in further information directly related to the activity, as well as general science and technology knowledge. This suggests that the activity has promoted not just knowledge about air pressure (the core scientific principle) but also practical skills, early science learning, and a broader interest in science and technology, at least among some participants.

From a conclusive perspective in this context, the Syringe Rocket exercise was a successful instrument for experiential learning, encouraging not just scientific knowledge but also practical skills, future learning interests, and creative thinking among participants. This demonstrates the importance of such hands-on, engaging activities in educational environments.

Summary of research findings from the Motivation and Learning Outcomes Interview (MLOI).

From the interviews that were conducted, it was found that both the parents and the children were interested in participating in the Syringe Rocket activity, enhancing their capability to ensure the balance between education and entertainment. Combining both, the participants indicated that they were interested in acquiring new skills contributing to the invention and innovation in the technical field, which also involved tool usage, creative thinking, and gaining knowledge that is beyond the learning facilitated in the schools. However, it is also a due note that there were various hurdles and barriers faced during the exercise. However, with the assistance and supervision of teachers and group leaders, everyone was able to successfully make their Syringe Rockets and develop a great deal of confidence in their abilities to invent. Furthermore, it can be seen that – the lecturer provided the scientific principles behind the Syringe Rocket. The hands-on activity allowed an easy understanding of the concept of air pressure scientific applications such as drilling, sawing, glue guns, and other functional items. Portraying these scientific items as game items leads to the complex mechanisms being perceived as game tools, allowing the completion of DIY projects.

4.6 Bricolage: Multi-Method Analysis

Multi-method analysis involves using more than 1 research method, to collect and analyze data in a specific research question/topic. Using a multi-method, primarily begins with performing research associated multiple sources of data collection tools and sources, which in this study is divided the seven-methodology implemented which are identified in the following illustration:

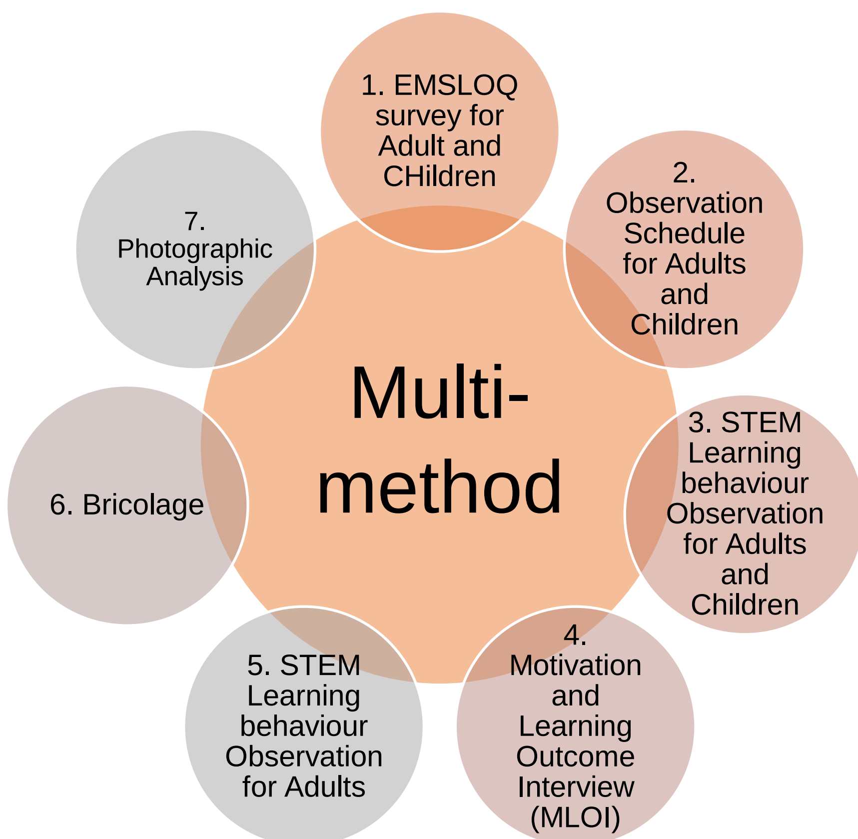

Figure 27: Multi-method Applied.

Once the researcher collated the findings from the six methodologies -- EMSLOQ survey for children and adults; Observation schedule for adults and children; STEM learning behaviour observation model for children and Adults; and finally, Motivation and Learning Outcome -- there was a rich tapestry of data that provided a multifaceted view of the subject matter. From this wealth of information, the researcher began the process of thematic analysis, seeking out patterns and recurring ideas that emerged consistently across the different methodologies. This involved a meticulous examination of the data, comparing the outcomes from each method. The goal was to find commonalities and discrepancies, trace patterns and trends, and look for insights that may otherwise be missed when focusing on the results of each methodology in isolation. The advantage of multi-method analysis is that a research study is capable of employing multiple data collection approach and analysis strategies, that allows addressing the key issues through perspectives such as, qualitative approach including observation and interview, quantitative method such as survey, as well as, using Bricolage for converging multiple findings from primary and secondary research study together. Each of tools of data employed in this study is further analysed and discussed and presented using a Bricolage analysis. The practice of Bricolage allows comparing multiple methodological orientation and analysis practices to procure richness and nuances in findings of a study. In evaluating each of the methodologies of the multi-method analysis, the following analysis is presented as follows:

- EMSLOQ Survey- The EMSLOQ Survey or the Environmental Motivational Survey of Learning Quality was designed to assess the motivational quality of educational requirements. The study was used to gather quantitative data and gaining insights on how the learning environment influenced motivational practices.
- Observation Approach- The observational approach was used for systematically observing, recording, and analysing the behaviour of both children and adults in the family in practicing collaborative and cooperative learning approach.
- STEM Approach for Adult and Children- The STEM approach includes evaluating the principls of science, technology, engineering, and mathematics that helps assessing how these learning can be incorporated for the students and enhance their learning experience.

- Motivation and Learning through Interview- The interview approach involved practicing one-to-one question-answer, which was designed to understand what motivated the individuals to learn. This included investigating and exploring how their individual experiences were connected, and what factors allowed exploring a connection between motivation, active participation, and acquiring knowledge.
- STEM Learning Observation for Adults- In addition to applying the STEM learning in exploring children and adult, the researcher also investigated the learning practice of the adults and how they were able to complement the learning practices among the children.
- Bricolage- The bricolage practice involves using multiple technologies and diverse rang of data sources, which allows involving criticality in the analysis practices. For instance, two different findings from different soruces can be usd to analyze the and gain a critical assertion on the learning practices of both children and adults.
- Photographic Analysis- The final analysis is a photographic analysis, which involves analysing the photos that were taken during the research phase. Although it stands as a part of observation, the photographic analysis allowed a further detailed understanding on the behaviour of children and parents together, and how they complement the learning practice.

4.6.1 Quantitative Data Findings Themes

1) Enjoy Makerspace Learning Outcomes Questionnaire (EMSLOQ): Children

- Family Learning- Participants acknowledged their family members engagement and aid in the activity, resulting in a collaborative and supportive learning environment.
- Experiential Learning- The survey results emphasised the participants varied capabilities, such as intellectual, problem-solving, communication, teamwork, and creative abilities.
- Immersion and Flow Experience- The survey results emphasised the participants varied capabilities, such as intellectual, problem- solving, communication, teamwork, and creative abilities.

- STEM Learning- Participants expressed significant agreement on their comprehension of science, technology, engineering, and mathematics principles incorporated in the Syringe Rocket exercise, as well as how these ideas were applied to the activity.
- Skills Development- The study found that the participants experienced enhancements in their learning, literacy and job and life skills as a result of the activity.
- Inspiration- In the study it was found that participants gained in learning, literacy, and job and life skills from the exercise.
- Creativity- The participants stated that the exercise made them creative and inventive, pushing them to produce new ideas and to experiment with new ways of problem solving.
- Learning Environment and Facilities- Enjoy Makerspace's general ambience, tools, and learning environment were conducive to learning and were therefore, liked by the participants.

2) NSM Enjoy Makerspace Learning Outcomes Questionnaire (EMSLOQ): Adults

- Positive Learning Experience - The Syringe Rocket activity was very entertaining and interactive for all participants at the Enjoy Maker Space. They indicated having gained different skills and knowledge particularly in STEM learning.
- Family Learning and Engagement - The Syringe Rocket activity was extremely enjoyable and engrossing in the Enjoy Maker Space. They stated that they gained numerous skills and information, particularly about STEM learning.
- Skill Development - The Syringe Rocket activity at the Enjoy Maker Space was highly enjoyable and involved people even more. They highlighted gaining diverse skills and knowledge, in particular, STEM learning.
- Motivation and Enjoyment - Participants found the exercise to be motivational, as they felt challenged, focused, and attentive throughout the procedure. They reported finding the activity fascinating, amusing, and pleasurable, leading to a desire to participate in such initiatives in the future.

- Creativity and Innovation - Participants reported feeling more creative and having innovative thoughts after participating in the Syringe Rocket exercise, which stimulated creativity and innovative thinking.
- Conducive Learning Environment and Resources- Participants were quite pleased with the learning environment and materials made available during the activity. They thought the location, equipment, and materials were favourable to learning and creating the Syringe Rocket, and that the assistance offered by the lecturer and assistant lecturer was invaluable.

The key themes that could be shared between the adult (parents) and the children participant's findings based on the interview findings suggested the following common factors – based on the makerspace Syringe Rocket activity. The common findings are presented as follows.

- Family Learning and Engagement- Firstly, both adults and children acknowledge that, family involvement can increase the level of creativity and experiential learning. This can further increase a supportive and collaborative learning environment among the family.
- Skill Development- The common findings between parents and children indicated that, both group of respondents were capable of acquiring a variety of skills as a result of participating in the makerspace Syringe-Rocket activity. Some of the common skills are associated with problem-solving, communication, teamwork, and creativity.
- Motivation and Enjoyment- The motivation and enjoyment factor suggested that, both adults and children had experienced significant challenge. However, it can be noted that, the respondents were motivated to learn from experienced associated with activities that were interesting, fun, and enjoyable. Hence, higher the engagement capacity of an activity, the greater the effect on the motivation to participate in the activity.
- Creativity and Innovation- Participating in the Syringe Rocket activity allowed the researchers were capable of fostering creativity and innovation, particularly in

terms of problem-solving capability. Furthermore, the parents had also supported their children that fostered an immersive experience.

- STEM Learning- Participants from both groups indicated a strong agreement on their understanding of science, technology, engineering, and mathematics concepts embedded within the Syringe Rocket activity, as well as the application of these concepts to the activity.
- Conducive Learning Environment and Resources- Both adults and children appreciated the learning environment, resources, and facilities provided during the activity, considering them conducive to learning and crafting the Syringe Rocket.

4.6.2 Qualitative Findings

1) Engagement Observation Schedule for Children

Before the activity-

- Engaged and cooperative with instructors
- Interested in materials and equipment.
- Excited about the activity
- Tense and anxious
- Interested in learning and asking questions
- Shy and lack of confidence in expressing themselves
- Interacted with family members
- Observed and studied the environment

During the activity-

- Highly active and participated in the activities
- Interested in creating their own projects
- Followed instructions and received help from instructors and parents
- More confident in their creations
- Willing to ask and discuss questions with instructors and assistants
- Involved in their own group
- Interacted with the environment and learned to choose materials and use tools

- Expressed enjoyment through their happy and excited faces
- Gained confidence in answering questions from instructors

2) Engagement Observation Schedule for Adults

Before Activities-

- Interest in tools and materials.
- Paying attention to the lecturer’s explanations.
- Encouraging children to ask questions and participate.
- Listening to the introduction of tools and steps.
- Experimenting and taking photos/videos of the activity.
- Conversations with other participants.
- Examining materials and assembling parts before starting.

During Activities-

- Actively assisting and guiding children in the project.
- Providing guidance and advice on using tools.
- Engaging in the activity with enthusiasm and interest.
- Asking questions, answering, and expressing opinions.
- Encouraging children to follow instructions and safety precautions.
- Helping children handle tools and complete the project.
- Collaborating with other family members in the activity.
- Conversing with assistant instructors and other parents.
- Assisting children in decoration and use of tools.
- Encouraging children to think, answer questions, and solve problems.
- Documenting the activity through photos and videos.

Based on the general themes identified in the observation schedule for children and adults, the following themes are grouped together-

Engagement and Interest-

- Engaged and cooperative with instructors

- Interested in materials and equipment
- Excited about the activity
- Interested in learning and asking questions
- Paying attention to the lecturer’s explanations
- Listening to the introduction of tools and steps
- Examining materials and assembling parts before starting

Emotional Response-

- Tense and anxious
- Shy and lack of confidence in expressing themselves
- Gained confidence in answering questions from instructors
- Expressing enjoyment through their happy and excited faces
- Engaging in the activity with enthusiasm and interest

Interaction and Collaboration-

- Interacted with family members
- Observed and studied the environment
- Involved in their own group
- Interacted with the environment and learned to choose materials and use tools
- Conversations with other participants
- Collaborating with other family members in the activity
- Conversing with assistant instructors and other parents

Active Participation and Support-

- Highly active and participated in the activities
- Interested in creating their own projects
- Followed instructions and received help from instructors and parents
- Willing to ask and discuss questions with instructors and assistants
- Actively assisting and guiding children in the project
- Providing guidance and advice on using tools

- Encouraging children to ask questions, participate, follow instructions, and safety precautions
- Helping children handle tools and complete the project

Problem Solving and Creativity-

- More confident in their creations
- Encouraging children to think, answer questions, and solve problems
- Assisting children in decoration and use of tools

Documentation and Sharing-

- Experimenting and taking photos/videos of the activity
- Documenting the activity through photos and videos

3) STEM Learning behaviour observation model for children

A. Basic STEM Knowledge and Skills-

- Mathematics- Measurement, estimation, and problem-solving.
- Science- Understanding of air pressure and scientific principles.
- Technology & Engineering- Material selection and technical understanding.

B. Skill Development and Learning Process-

- Limited foundation in STEM skills.
- Need for guidance and instruction in using complex tools.
- Problem-solving and adaptability.

C. Collaboration and Support-

- Assistance and guidance from instructors and parents.
- Teamwork and communication with family members.

D. Creativity and Enjoyment-

- Enjoyment in the decoration process.
- Application of mathematical skills for creative purposes.
- Engagement and interest in the activity.

4) **STEM Learning Observation model for adults**

A. **Basic STEM Knowledge and Skills-**

- Mathematics- Measurement, estimation, and problem-solving.
- Science- Understanding of air pressure and scientific principles.
- Technology & Engineering- Material selection and technical understanding.

B. **Skill Development and Learning Process-**

- Limited foundation in STEM skills.
- Need for guidance and instruction in using complex tools.
- Problem-solving and adaptability.

C. **Collaboration and Support-**

- Assistance and guidance from instructors and parents.
- Teamwork and communication with family members.

D. **Creativity and Enjoyment-**

- Enjoyment in the decoration process.
- Application of mathematical skills for creative purposes.
- Engagement and interest in the activity.

5) **Motivation and Learning Outcome Interview (MLOI)**

A. **Interest and Engagement-**

- Fun and hands-on learning experience.
- Attraction towards activities that foster creativity and skill development.

B. **Skill Development and Confidence Building-**

- Acquiring new skills in invention, tool usage, and creative thinking.
- Overcoming challenges and obstacles with guidance from instructors and group leaders.
- Increased confidence in their ability to create and invent.

C. **Learning and Understanding of Scientific Principles-**

- Clear understanding of the concept of air pressure.
- Visualisation of scientific principles at work.

D. **Desire for Continued Learning and Exploration-**

- Interest in expanding knowledge and skills in science, invention, and creativity.
- Exploration of functional items, toys with complex mechanisms, and more science-related DIY projects.

E. **Collaboration and Support-**

- Active involvement of both children and parents.
- Assistance and guidance from instructors, group leaders, and family members during the activity.

4.6.3 Collaborative Conclusive Themes

Based on the quantitative and qualitative findings from the Enjoy Makerspace Syringe Rocket activity, the following key themes can be grouped together, which the researcher interestingly noted to contribute mainly to the themes of the quantitative study. Therefore, the benchmark used in the analysis was utilising all the main themes of the survey, followed by new themes identified.

Themes	Description
A. Family Learning and Engagement (Active Participation and Support)	• Importance of family involvement • Supportive and collaborative learning environment • Interaction and collaboration among family members • Willingness to ask and discuss questions with instructors and assistants • Parents actively assisting and guiding children in the project • Assistance and guidance from instructors
B. Skill Development	• Problem- solving, communication, teamwork, and creative thinking skills • Acquiring new skills in invention, tool usage, and creative thinking • Confidence building through overcoming challenges and obstacles

Themes	Description
C. Motivation and Enjoyment	• Fun, hands-on learning experience • Interest in expanding knowledge and skills in science, invention, and creativity • Desire for continued learning and exploration
D. STEM Learning	• Understanding and application of science, technology, engineering, and mathematics concepts • Basic STEM knowledge and skills development • Learning and understanding of scientific principles
E. Creativity and Innovation	• Fostering creativity and innovative thoughts through the activity • Enjoyment in the decoration process • Application of mathematical skills for creative purpose
F. Conducive Learning Environment and Resources	• Positive learning environment • Appreciation for the resources and facilities provided • Assistance and guidance from instructors and group leaders
G. Emotional Response	• Tense and anxious to confident and engaged • Shy and lack of confidence to expressing enjoyment and enthusiasm • Active participation and support
H. Documentation and sharing	• Experimenting and taking photos/ videos of the activity • Documenting the activity through photos and videos

Table 38 : Conclusive Themes

These themes provide a comprehensive understanding of the participants' experiences and learning outcomes from the Enjoy Makerspace Syringe Rocket activity, highlighting the importance of family engagement, skill development, motivation, STEM learning, creativity, conducive learning environments, emotional response, and documentation and sharing in the learning process.

In analysing this, the Enjoy Makerspace Syringe Rocket activity highlights how makerspaces contribute to a range of positive learning outcomes and experiences for participants. Makerspaces encourage family involvement and provide a supportive and collaborative learning environment. They foster interaction and collaboration among family members, prompting open discussions with instructors and assistants. In such a manner, parents were participating in the learning process of their children by means of assistance and guidance to their children in implementing the project. The makerspace program provides the perfect setting for families to build a community bond and interactive learning opportunities. This also leads to the development and strengthening of important skills, such as critical thinking, communication, collaboration, and imaginative thinking processes.

Besides, it became clear that the participants had gained new skills in arts, crafts, and creative development, which helped them to grow in confidence by tackling problems and finding solutions. Particularly, this acted as a crucial skill acquisition forum, meeting the varied learning requirements and preferences of the buyers. However, the makerspace program is not only limited to learning and education but rather oriented towards the edutainment concept. In other words, the makerspace program emphasises expanding knowledge and skills in terms of science, invention, and creativity – with continued effort towards learning and exploring practices. This eventually contributes to the fostering of participant's understanding of complex subjects like science, technology, engineering, and mathematics. Therefore, through the edutainment program under STEM, the children can apply basic STEM principles, knowledge, and skills and enhance their creativity. Furthermore, it can also be recognised that shy individuals lacking confidence can transform into enthusiastic learners who actively participate and support others. Hence, contributes to the development of emotional intelligence (EI) by helping participants transition from feeling tensed and anxious to becoming confident and engaged.

Lastly, makerspaces encourage documentation and sharing as participants experiment and take photos or videos of the activity. This practice not only helps in preserving memories but also allows learners to showcase their creations and experiences, inspiring others to engage in makerspace activities. Resultantly, makerspaces play a crucial role in nurturing various learning outcomes, fostering an inclusive and conducive environment for skill development, family engagement, and the promotion of STEM subjects.

4.7 Discussion

The discussion section would be vital in this final research, as it would categorise the primary and secondary findings and address them in accordance with the research objectives and research question. The study's aim was to investigate the process of family visitors becoming makers in the NSM Enjoy Makerspace, at the NSM, Thailand. In addressing this aim, the following objectives were presented:

- To develop family visitors learning through NSM Enjoy Makerspace activities at the National Science Museum, Thailand.
- To describe the factors that encourage family visitors to learn as a maker through NSM Enjoy Makerspace.
- To study family visitors learning outcomes through NSM Enjoy Makerspace
- To explore family visitors motivation, knowledge, skills, inspiration, and creativity from NSM Enjoy Makerspace via the focus on family learning, experiential learning, flow and immersion and STEM learning.

Resultantly, the researcher has broken down this section based on research objectives and how both the findings from primary and secondary data has contributed to its probable conclusion.

4.7.1 Improving Family Learning through NSM Enjoy Makerspace Activities

The NSM Enjoy Makerspace at the National Science Museum was designed to promote and encourage learning through creativity and practical application of skills. The Makerspace offers visitors resources like tools and materials, background information and suggested activities such as the Syringe Rocket activity, which allows the visitor to engage in constructive play and learn through the application of their imagination and creativity. Moreover, an "educator" from the museum stands ready to lend their expertise should the need arise. Supplementing the comprehensive aids are skilful assistants who lead participants through the necessary use of tools and machinery. It is more than a workspace as it is an engaging, interactive sanctuary where ideas are generated and developed to reality under the guidance.

In this setting, the research used innovative ways of promoting family learning. The syringe activity is one of the methods that were specifically implemented in this study, which involved making a rocket and where families, including children and adults, were grouped as families and asked to participate in producing it. The NSM also provides other types of activities that should have been covered in the study, which change from time to time. During the study, other activities were a textile activity (tie-dying with reactive dyes) and a free-style balsa wood construction activity. The National Science Museum's (NSM) Enjoy Makerspace presents an array of activities that catalyse family learning, facilitating the nurturing of intellectual curiosity and the development of scientific literacy within the familial context through activities like science films and interactive exhibits. The utilisation of science in creating a collaborative demonstration of scientific phenomenon could increase immersion and education experiences for the participants.

In Thailand, a country known for its vibrant culture and strong emphasis on education, there is a significant commitment to lifelong learning, particularly within the spheres of science and technology. This is evident in the initiatives of the Thai government, especially through programs such as the "NSM Enjoy Makerspace" hosted by the National Science Museum (Ratana-Ubol and Henschke, 2015). It can be observed that the Thai cultural concept is the emphasis of lifelong learning, a point that is supported by

Charungkaittikul and Henschke (2014) who highlight that this tradition is deeply rooted in the Thai society. Education is imparted to individuals not only for personal growth but also to contribute towards social development through keeping abreast of modern developments and technology. Further, in a large measure, in Thai culture learning is a community affair that transcends individual personal achievement. This has been illustrated by Sungsri (2009) and Richards et al. (2019) which research accentuate the importance of family learning in the Thai context. This partnership approach is also reflected in government programs in which families are often given opportunities to study together through practice.

A variety of family learning activities have been designed and carried out in Thailand, with the objective of implementing or hands on learning and encouraging the development of a culture of lifelong learning. Some of the professional development opportunities that are available to teachers in Thailand are Science and Technology Workshops, Maker Faires and STEM Festivals, Mobile Science Centres, and Online Learning Platforms (Soratana et al., 2021; Kanhadiklok, 2013).

Hence, the NSM Enjoy Makerspace is a whole-brain place that tickles the intellect, nurtures a learning style, and perpetuates family learning in an enjoyable, interactive and harmonious way. The diversity of activities, the employment of the state-of-the-art technology, and the focus on family involvement have all made the Makerspace a learning centre. Moreover, these programs have also fostered the culture of lifelong learning, cooperation, and innovation on the visiting families of the National Science Museum Thailand.

4.7.2 Factors Encouraging Family Visitors to Learn as a Maker through NSM Enjoy Makerspace

Identifying the factors that encourage family visitors to participate in NSM Enjoy Makerspace was a crucial part of the research. Based on the primary data collected, various motivators were identified. The findings of the study indicate that various factors contribute to encouraging family visitors to learn in the NSM Enjoy Makerspace. These factors were categorised into three main themes: engaging learning experiences, a conducive environment, and a community-oriented setting.

A crucial element is the interactive nature of the makerspace, which facilitates an environment conducive to immersive learning, which, in other words, can be called an engaging learning experience. Furthermore, the observation and the interview responses indicated that the hands-on experiences among participants were found to stimulate a higher level of immersion and experience compared to conventional learning experiences. Herein, the participatory activities, including the building of rockets, also further fostered a strengthening familial relationship, with the chance to learn and increase the practical learning experience. In addition to that, the findings also indicated that collaborative learning could also lead to be a strong motivator of participating in learning activities. This corroborates with theories of experiential learning (Kolb, 1984, cited in Murrell and Claxton, 1987), which highlight the value of direct experience in the learning process. The hands-on activities presented in the makerspace not only foster creativity but also stimulate curiosity, which acts as a potent motivator for learners.

Moreover, the family-friendly design of the NSM Enjoy Makerspace significantly contributes to its allure. As the space encourages group activities and collaborative learning, it inherently promotes bonding among family members. This aspect resonates with the cultural context of Thailand, where learning is often viewed as a communal activity. Families enjoy engaging in the shared process of creation, discovery, and exploration, which further encourages learning within the makerspace. Therefore, the Makerspace's community-oriented setting contributed to its appeal. The opportunity to interact with other families, share ideas, and learn from others was seen as a unique and valuable experience. This corroborates with Lave and Wenger's (1991) theory of situated learning, which proposes that learning occurs in a social context.

Interestingly, one more noteworthy aspect of NSM Enjoy Makerspace is the way it manages to instil a sense of ownership and autonomy in the learning process, which further propels family visitors to learn. Allowing participants to choose the projects they want to work on and the methods they want to employ bestows them with a sense of control over their learning journey. This autonomy helps in boosting confidence, engagement, and overall learning. As Deci and Ryan's (1985) self-determination theory suggests, environments that support autonomy foster intrinsic motivation, resulting in higher levels of persistence, creativity, and overall satisfaction.

Another influential factor is the sense of accomplishment that participants feel upon completing a project. This sense of achievement made the learning activity more fulfilling and enjoyable. The rewards are not limited to the tangible output of the activity but also include the mastery of new skills and the deepening of scientific understanding. This aligns with the competence aspect of self-determination theory (Deci and Ryan, 1985), which proposes that individuals are motivated by a desire to feel effective in interacting with their environment. The integration of technology within the Makerspace also sparks interest and encourages learning. While the technology used in the Rocket Syringe activity was minimal (including some construction tools and some information technology), it still proved to be interesting and engaging for visitors. This exposure can lead to a better understanding of the role of technology in society and its potential applications in various fields.

Moreover, learning to navigate these technologies equips individuals with skills that are increasingly valuable in today's digital age. This is an interesting area where the NSM Enjoy Makerspace could have a much higher impact compared to what was observed in this research since the research focused on one of the simpler, all-ages activities. The Makerspace also has more cutting-edge technologies, such as 3D printers, available for visitor use. Investigating the impact of independent use of these more advanced technologies is an area where the research could be furthered, either within the context of the NSM Enjoy Makerspace or in others.

In addition, the emphasis on an enjoyable atmosphere within the Makerspace significantly contributes to its appeal. The playful aspect of the learning activities makes them less intimidating and more approachable, allowing families to explore complex scientific concepts with ease. This corroborates with theories on the role of play in learning (Pellegrini and Smith, 1998), which propose that play serves as a mechanism for learning by providing opportunities for exploration, hypothesis testing, and problem-solving.

Resultantly, it can be argued to the context of this study and the extent of what has already been discussed that the engaging learning experiences, the conducive environment, the community-oriented setting, a sense of ownership and autonomy, exposure to cutting-edge technology, the feeling of accomplishment, and the fun and enjoyable atmosphere, all play a critical role in encouraging family visitors to learn as a maker in the NSM Enjoy Makerspace. These factors, individually and collectively, create a unique learning environment that stimulates curiosity, fosters creativity, and enhances motivation for learning.

4.7.3 Learning Outcomes from NSM Enjoy Makerspace

Investigating the learning outcomes of family visitors through NSM Enjoy Makerspace was another key objective of the study. The study of both primary and secondary data reveals that the participatory learning activities in the Makerspace substantially influenced the outcomes of education in a variety of aspects. According to the results of this research, it was specified that the learning flow among the children seems to flow through various actions and practices, for example, hands-on experiences and collaborative character of makerspace activities. In addition, the focus on flow learning aims to enhance the participant's experiences and create a high level of participation and pleasure. Furthermore, research results as well revealed that experiential learning stimulates immersive learning at the same time, which promotes creative thinking abilities. These have also been developed in previous literature by Michailidis et al. (2018), and also by Linkinen (2019), who suggested that the harmonious balance between the skills of an individual and the challenges presented promoted flow, that was characterized with the complete immersion in the activity at hand. Such a flow state, as the research discovered, is created by the variety and practical aspect of activities in the Makerspace, being an ambience where enriched learning experiences happen. Flow, as defined by Csikszentmihalyi, is a state of complete engagement and total focus where individuals lose their sense of self and time, feeling intense pleasure. This stage is critical in developing the love of learning and deepening the level of understanding.

However, immersion is the intensity of involvement and presence an individual has in an activity. In Makerspace, the participatory and hands-on aspects of the activities make this immersion possible, allowing children to immerse themselves in the materials and becoming truly connected with them to improve their creative thinking. Eventually, collaborative flow is a situation that people attain flow while interacting with one another to confer their skills and actions. Such collective flow is developed in the Makerspace environment, which promotes a collaborative mode and therefore strengthening the learning process and outcomes. The partnership between solo dedication and teamwork helps to create a live teaching atmosphere, which has a great impact on creative thought and participation. What can be interpreted is that the findings from the study are in line with Michailidis et al. (2018) and Linkinen (2019), therefore, implying that learning experiences and outcomes can be improved through flow, immersion, and collaborative flow within the Makerspace context.

4.7.3.1 Enhancement of Understanding of Scientific Concepts

One of the remarkable advantages of the NSM Enjoy Makerspace is the way it demystifies the abstract and complex scientific concepts for the participants of all ages. Families experienced a significant increase in their comprehension of diverse scientific concepts. By keeping themselves directly involved in such practical activities families could go deeper into the topic, create more tangible knowledge when compared to the passive intake of information. The notion of passive learning was further discussed in the past findings, as proposed in the study by Kaltman (2010). The findings of Kaltman (2010) confirmed that a passive learning experience allows improved learning ability and improvement – which could include triggering the senses of smell, touch, sight, and others.

An example could be focusing on the acoustics of the learning environment, thereby preventing noise contamination to ensure effective delivery of the message. This type of learning environment promotes the transformation of theoretical knowledge into applied understanding, thus reinforcing the comprehension and retention of scientific concepts. These reports can be explained through Kolb's Experiential Learning Theory (1984), which propounds that knowledge results from the transformation of experience, and learning is more effective when an individual is involved in the task at hand. The activities in the Makerspace, by requiring participants to directly engage with scientific principles and apply them to a real-world task, may facilitate this transformative learning process. In addition to the study by Kolb, Mezirow's theory on the transformative learning process commonly cites that learning students better in a controlled environment compared to those that were not – and more specifically, in an authentic environment of the learners. Consequently, they could contribute significantly to enhancing scientific literacy among the participants. However, as the research did not include a formal learning or skills assessment as part of the research design, this is something that cannot be proved through the study. It remains an area for further research, potentially in a more rigorous learning experiment approach.

4.7.3.2 Skill Development

The activities in the NSM Enjoy Makerspace not only enhanced the participants' understanding of scientific concepts but also promoted the development of a range of crucial 21st century skills. Participants learned to approach problems in novel ways, devise innovative solutions, and make informed decisions, thereby honing their problem-solving and critical-thinking skills. In line with the Maker Movement's emphasis on learning through failure, participants were encouraged to perceive mistakes not as endpoints but as steppingstones towards greater understanding, thereby fostering resilience and adaptability. One of the key learning points in skill development is the concept of "learning by failure". Referring to the literature review, it could be granted that "learning by failure" could impede negative consequences among the learners, as this could produce negative emotions and frustrations. Therefore, it is important to ensure collaborative development and support from the family members and tutors during the learning period. In addition to the development of innovation and creativity as a skill, the makerspace activity also contributed to fostering soft skills such as collaboration and communication. As the makerspace activity requires both parents and children to work together, this increased and improved the collaborative skills, enhancing a shared goal, and helped families not only enhance their interpersonal skills but also contributed to the fostering of a sense of unity and mutual understanding. In addition to that, the study by Pattison and Dierking (2012) stated that, in some instances, the interaction between family members could also result in negative consequences. This can be dependent upon factors such as the family learning behaviour, family dynamics, and the pre-existing learning practices of the family. Hence, the role of the makerspace activity, in this case, is significant, as it allows for bridging the communication gap between the families and the children. Alongside such, the nature of the makerspace activity also strongly emphasises openness and flexibility and, therefore, allows the participants to "think outside the box". As reported by Robinson (2011), pedagogical approaches to teaching and learning should be combined with the concept of freedom to experiment, which can enhance the level of creativity and innovation. This can range from aspects such as creating and devising unique solutions to allowing participants to unlock their potential subjected to their internal development.

4.7.3.3 Affective Outcomes

Affective outcomes are defined as emotional factors that influence the learning process, which can have a negative/positive effect on individual behaviour. In the study by Jaatinen and Lindfors (2019), some examples of emotional factors included elements such as pride and frustration, which was a resultant effect of being successful in attaining each task objective or failing. Although the concept of learning by failure can be acknowledged as a part of experiential learning, the frustration experienced by the learners could lead to project failure. Despite being one of the limitations of the experiential learning approach, the NSM Enjoy Makerspace allows, engages and conveys activities associated with the interactive and hands-on nature of the activities. This makes learning an enjoyable experience that is capable of evoking emotions such as curiosity, intrinsic motivation to learn, freedom and flexibility to experiment and provides a self-paced learning experience. Combined, the interactive and hands-on nature of activities can contribute to what, effectively, can be viewed as a rewarding learning experience for the participants of the NSM Enjoy Makerspace.

Furthermore, during the data collection stage – it was further observed that – the completion of the Syringe Rocket project allowed achieving a sense of achievement and improved the level of self-confidence among the children. This is in line with the Self-Determination Theory proposed by Deci and Ryan (1985). The findings by Deci and Ryan (1985) clarified that completion of complex tasks can increase the sense of competence, enhance the intrinsic motivation to learn and ensure sustained interest in learning activities. Referring back to the study by Jattinen and Lindfors (2019), the completion of the study can also yield positive emotions, such as pride among the learners, which can register as a meaningful learning experience among the learners.

4.7.3.4 Strengthening of Familial Relationships

As the earlier benefits of using the NSM Enjoy Makerspace on an individual level, the benefits of the makerspace activity beyond individual learning and may have positively affected the family as a whole. There are some potential positive effects of family learning, according to the family learning theory of Desforges and Abouchaar (2003). This theory states that shared learning experiences between family members could enhance the learning experience and familial relationships. Hence, overcoming challenges together in a parent-child relationship and the joy of shared discovery can improve and strengthen the familial and emotional bond. This can be a considerate development of the children's openness with their parents and could reflect on the children's appreciation of strengths and talents for fostering a deeper understanding and respect for each other (Desforges and Abouchaar, 2003). In addition to that, the study by Ellenbogen et al. (2004) cites that the presence of family-based activities can also improve the overall relationship within a family unit that is not necessarily visible from the outside. In addition to the familial relationship, the findings proposed by Wyk and Haffejee (2017) also confirmed that the use of museum-based learning and collaborative training experiences can have a higher achievement rate and significant impact on peer-based learning despite being from different cultural backgrounds. However, this is an area where the research was not as successful at uncovering outcomes compared to individual learning. For example, while children were relatively open about their own learning experiences, they did not reflect on their experience of learning with family members or any effects on emotional ties. This is unsurprising given the relatively short time in which families were involved in the experiment, which did not give children particularly much time to get comfortable. However, it is something that should be addressed in later research, as this is an important aspect of family learning. In line with the gaps identified, future research studies can, therefore, also focus on specific goals of developing family-learning experience, reviewing how family communication, specifically parents and guardians, can enhance the learning and communication skills to help their children and improve familial bonds.

4.7.3.5 Fostering a Lifelong Love for Learning

The NSM's Enjoy Makerspace program has been established to create an immersive and collaborative learning practice, ensuring ease of learning combined with depth of learning experiences. The integration of entertainment and education can, therefore, drive an enjoyable learning experience, helping shift the participant's perception of the conventional, tedious learning process. Furthermore, the autonomy of decision-making provided by the makerspace allowed the participants to take ownership of their learning at their own pace, further reinforcing the intrinsic motivation towards learning new aspects. Hence, the combined effects of ownership in learning, enjoyable and rewarding experience, and allowing the completion of tasks in a self-paced manner increases the desire to learn more. This has also been theorised in the paper by Deci and Ryan's (1985) self-determination theory, which states that individuals who are self-motivated and hold the desire to understand new concepts are inclined towards having a sustained interest in the successful application of learning means.

Furthermore, this could stimulate sustained learning and interest in science and technology (parts of STEM) and encourage the participants, like the children, to gauge further into these learning concepts. Hence, the NSM's Enjoy Makerspace can be marked as an initial learning seed for children to explore their lifelong learning process. The

Makerspace, thus, served as a platform for social interaction and community-building, fostering a vibrant and inclusive learning community.

In conclusion, the study demonstrated the significant benefits that participation in the NSM Enjoy Makerspace conferred on family visitors. Furthermore, the makerspace served as a platform for communication and collaboration, helping participants to excel in furthering their crucial skills, experience, and a sense of community. The findings also underscore the value of makerspace in supporting meaningful and impactful learning experiences.

4.7.3.6 Community Building and Social Interaction

The makerspace also acted as a hub for community building and social interaction. At the familial level, the project collaboration has interacted with other participants, leading to a lively exchange of ideas and experiences. In a familial environment, this fostered a sense of community and a sense of belonging – that served as a platform for social interaction and community building. The concept of a sense of belonging, as referred to in the paper by Koh et al. (2018), was found to be stronger in and among the Thai community, which orients towards the concept of collectivism. Community building and social interaction are embedded within the Thai community, which orients towards investing and promoting the concept of group dynamics. Investing in makerspace activities can allow further uplifting of the stages of learning, such as the concept of a sense of camaraderie, enhanced learning among family members and peers, and ensuring knowledge sharing.

Furthermore, the literature reviews also suggested that the implementation of group development practices can be significant in ensuring a sense of belonging among individualistic countries such as the United States and the United Kingdom – whereby establishing a steppingstone and progressive approach to retain better bonds and relationships. At the same time, there was also evidence of community building and social interaction happening outside the boundaries of the family. This included pre-existing communities visiting the museum, such as groups including several mothers bringing their children to the museum together. It also included ad hoc social interaction between children in different groups, who often worked together or in “parallel play” fashion on the activities, whether or not they were related. Thus, there is a potentially more powerful opportunity for the makerspace to act as a learning community hub across and outside the boundaries of the family as well. This further strengthens the visualisation and identification of the definition of makerspace, as proposed by the study of Vongkulluksn et al. (2018), who confirmed that makerspace establishes a sense of community and belongingness, whereby the makers or the learners are capable of engaging with peers of their demographics, which can further strengthen and encourage personal growth and development.

4.7.3.7 Promoting Diversity and Inclusivity

The concept of diversity has been one of the inclusive concepts of the Strategy for Family Learning within the Family Action Plan 2020-2022, as proposed by the OPS MOAC of Thailand. The review of the literature on the Family Action Plan, as proposed by Opsmoac.go.th (2020), confirmed that diversity can be retained based on factors such as gender diversity, cultural diversity, and others, which could enhance the creative capability and shared bonding among the members of the makerspace. In line with such, based on the findings of this study, it was further observed through the surveys and other data collection processes that the NSM Enjoy Makerspace received visitors from diverse backgrounds. Its activities and resources promote inclusive participation in making. Its open and inclusive environment fostered engagement from families from all occupations. Participants in the NSM's makerspace program were also encouraged to approach projects based on their own cultural experiences and ideas, promoting an environment of cultural interchange and appreciation. The adoption of culture as a mainstream aspect of promoting makerspace activities ensures its inclination with the policies proposed by the National Education Commission (2002), which ensures that the knowledge regarding religion, art, culture, and Thai wisdom is properly disseminated among the learners. The Makerspace enabled an inclusive learning atmosphere that embraced diversity by fostering diverse viewpoints. The diverse family structures and styles of interaction contributed to a rich tapestry of ideas and perspectives, enhancing the group learning experience. Hence, the combined aspects had improved diversification that contributed to enhanced learning experiences. It would be beneficial in future research to extend observations on diversity and inclusion, for example, to consider the NSM Enjoy Makerspace's accessibility to families from ethnic minority groups, LGBT+ -led families, and tourists and immigrant families, among others. Although the literature of this study delves into the limited concept of diversity and inclusivity, it can be confirmed that these factors are aligned more respectively towards the national education guidelines, as well as the sustainable development goals followed by the Thai government – which is, ensuring inclusive and equitable education and promoting lifelong learning opportunities for all.

4.7.3.8 Role in Supporting Formal Education

Finally, the Makerspace supported participants in their formal education. The Makerspace's practical use of scientific principles helps to contextualise and reinforce what members acquired in school. The exercises supplemented classroom learning by adding a layer of comprehension that textbooks could not provide. This enhanced comprehension may increase participant's formal education performance, highlighting the importance of outside-of-class learning contexts in enhancing academic progress. In the setting of Thailand, the environment of experiential learning is more constrained in comparison to the traditional classroom. Nevertheless, according to the research provided by Nakamura and Csikszentmihalyi (2014), and Schweder and Raufelder (2021), the use of experiential learning and enhancing the classroom with flow-learning principles – can create an integration of cognitive and emotional learning activities.

In addition, the notion of makerspace learning can be spread throughout the regular classroom, thus, providing a holistic learning opportunity for the pupil. This notion also favors learning that is based on practice and flow-based learning, quickness of feedback, and control in the learning process. Moreover, it is crucial to add that skills acquired at the Makerspace, such as critical thinking, problem-solving, and collaboration, are transferable and highly applicable in school contexts. Those skills help in handling the academic issues, thus, promoting academic success and even a complete development. The research of Jaatinen and Lindfors (2019) and Schweder and Raufelder (2021) also highlighted that flow experiences are part of specific authentic educational practices. The

Finnish craft schools have as well advocated for unstructured, activity-based and learner-initiated learning and teaching.

4.7.3.9 Implications for Future Makerspaces

The advantages of NSM Learn Enjoy Makerspace should be taken as an important resource of knowledge for the future Makerspace development. Future Makerspaces could include aspects of experiential learning, skill development, affective outcomes, family linkage, lifelong learning, community building, diversity and inclusion, and support to formal education to enhance learning outputs. This could involve offering various resources and tools, crafting diverse and fun activities, fostering a warm and inclusive atmosphere and engaging in socialization and collaboration. This study brings to the fore the great learning resource potential of Makerspaces. Makerspaces have the potential to facilitate inspiring learning progressions that are responsive to diverse learning needs and styles, promote all- round development, and cultivate the culture of lifelong learning through creative design and practice.

4.7.4 Family Visitors Motivation, Knowledge, Skills, Inspiration, and Creativity

The last purpose of the study was to look at motivation, knowledge, skills, inspiring and creating of family visitors to NSM Enjoy Makerspace. A mixed source of primary and secondary data showed that, Makerspace, effectively encourages these aspects.

4.7.4.1 Motivation of Family Visitors

The initial facet of the final research objective dealt with the motivational aspects driving family visitors engagement with the NSM Enjoy Makerspace. An amalgamation of primary and secondary data manifested a direct relationship between the intriguing, interactive nature of the Makerspace activities and the heightened motivation among family visitors. Resonating with the principles of Deci and Ryan’s (1985) self-determination theory, which suggests that environments endorsing autonomy, competence, and social connection effectively foster intrinsic motivation, the Makerspace emerged as a strong catalyst for motivational enhancement. Furthermore, aligning the findings with the study by Dillenbourg (1999), followed by the papers of Bonwell and Eison (1991) and Kuboet al.

(2011) – it was confirmed that collaborative approaches could allow students and learners to have motivational aspirations. The Makerspace's participatory approach, its facilitation of hands-on experiences, and the autonomy granted to family visitors empowered them to learn and experiment freely. The concept of autonomy, in this case, stands out as Deci and Ryan (2015) stated that the presence of autonomy can lead to satisfactory rewards. More specifically, in the context of NSM Makerspace Activity, autonomy in project selection can significantly impact community collaboration and encourage relatedness through familial engagement. The rewarding sense of achievement gained upon completing a project further amplified their motivation, pushing them to take up more challenges and deepening their engagement with Makerspace.

4.7.4.2 Enhancement of Knowledge and Skills

The second aspect of the research objective focused on the knowledge and skill acquisition resulting from family visitor's interaction with the NSM Enjoy Makerspace. A blend of data indicated that Makerspace's practical, hands-on activities empowered participants to delve deeper into scientific concepts and develop various skills, most notably problem-solving and critical thinking. Combining problem-solving and ensuring higher concentration and motivation through experiential and experimental study strategies could contribute to immersive and flow learning. The study's findings further showed that organised learning within the NSM makerspace fosters these immersive and flow-learning practices – as referred to in the study by Stetsenko (2017). The research study by Stetsenko (2017) further confirms that NSM makerspace activities can also help develop and construct new knowledge and intelligence among the learners that can be better compared to the traditional learning environment. Overall, the active engagement and experimentation process contributes to the "learning by doing" concept and significantly bolsters the comprehensiveness of theoretical and scientific concepts. Herein, the opportunity to manipulate materials and tools directly, coupled with the guidance and mentorship of skilled educators, – aids and fosters a path that is a highly effective and practical learning experience.

4.7.4.3 Inspiration and Creativity

inally, the findings of this study aimed to evaluate the role of NSM enjoy makerspace in inspiring family visitors and fostering overall creativity. The makerspace enhances the individuals capability by allowing them to think outside of the box, which also allows a form of experience-based learning, which psychologists refer to as "flow-learning". The study by Radovic et al. (2021) defined flow learning as a pillar of experiential learning, allowing learners to engage in an optimal state of immersion and focus. Flow and immersion state, where people are completely involved in the task that suits their abilities can enhance their feeling of achievement and motivate them even more, generating creativity and development. Apart from that, this also stimulates and sets up an increased level of force to the development of inspiration and creativity, which improves the ability of individual to go beyond their development boundaries. Makerspace fostered an environment where trial and error was not only tolerated, but welcomed, thus, stimulating a culture of creative risk-taking. This atmosphere produced innovative original ideas and inventive ways to solve problem-solving activities, thus, providing further evidence of the indispensable role of Makerspaces in promoting creativity. In the same vein, the makerspace offered an environment in which trial and error were not only tolerated, but also promoted, and consequently, nurtured a culture of creative risk-taking, which facilitated participant's entry into the flow state (Oliver et al., 2021). This setting brought about generating original thoughts and innovative ways to problems solving tasks, besides proving the significance of makerspaces in the support and promotion of creativity.

This analysis shows the fact that Makerspace influence goes beyond knowledge and skill delivery. It also efficiently boosts participants' motivation, triggers motivation, and fosters creativity, resulting in a well-rounded learning process. Benefits of family visitation could be optimized by Future Makerspaces that include these elements.

4.7.5 Gender and Technology in STEM Learning

The researcher also gathered demographics info and utilized technology during the study for better learning. Considering the results of the study, one of the factors included in this study is a brief discussion of gender. The demographic finding of the study showcased that, the ratio of male to female participants in the study group was 2:Part 1, 60% males and 30% females. This demographic profile is a representation of the general trend in STEM fields where male participation is predominantly higher than female. Nevertheless, further analysis of the subtlety of such statistics is important, especially in terms of how they lead to engagement and learning outcomes in mixed-gender educational environments including the makerspace. The number brings up the issue regarding the convenience of STEM fields as well as popularity of STEM fields as a career choice in diverse gender from an early age. This asymmetry is a reflection of wider societal dynamics and stereotypes found in STEM, highlighting the need for intervention strategies that would promote gender equality from the grass-roots levels of education. Targeted programs aimed at female participants in STEM could help overcome this gap, hence resulting in a more balanced representation of a future group of professional participants in the STEM fields. It was noted through observational analysis indicated that, the gravity of differences between the male and female participants in terms of the rocket science project was very minimal. However, it was noted that, age had a higher relevance with the STEM learning process, wherein, with increasing age, the children had a strong learning experience. Furthermore, it was noted that, children and infant had greater challenge towards learning experience.

This observation highlights the need for the development of age-appropriate STEM curriculum that meets the developmental levels of children. Adapting the complexity and the format of the STEM activities may increase the attention and learning performance, which may make STEM topics more interesting and understandable. The diversity of teaching methods as such is essential for building an early interest and confidence in STEM areas.

Research studies such as Seo and Richard (2021) and Steele et al., (2018) further reported that, gender and learning experience in makerspace noted that, gender is a key attribute in defining the attribute of children, exploring their change in behaviour. However, the NSM makerspace activity in this study was limited in this study. The limited differentiation that is evident in this study between genders in terms of involvement and outputs in makerspace activities is an indication that when afforded equal chance and resources, gender inequalities in STEM interest and achievements can be reduced. This result can be used to inform what should be done in education to promote an inclusive and gender-neutral learning environment that fosters participation of all genders equally. In addition to that, several studies such as Christensen (2002) and School of Education (2020) reported that, technological integration is a key factor in influencing educational practices. Tablets and other digital gadgets in the learning process is a radical reinforcement of the development of education through technology. This change is in line with the digitalization of the society and makes available various opportunities for interactive and individualized learning experiences. Nevertheless, it raises the problems of providing equal access to technology and the internet for all students, placing the digital divide at the center of the problems to solve in the equitable use of technology in education. In this study also, a tablet was used for the immersive learning practice. The use of tablet, as well as other technologies such as virtual reality (VR) and augmented reality (AR) technology is also recognized to have a significant impact on educational practices. Tablets in this study was used for ensuring and recognizing independent learning practices, with Harris et al., (2023) reporting the leanring approach effecvtive for children. Use of technology such as tablets, VR, and AR in STEM learning does not only make the learning process more interesting but also substantially improves the depth of understanding due to the fact that it provides immersive and interactive experiences. These technologies can bring to life complex scientific phenomena or engineering processes in practicable ways, thereby, making abstract ideas concrete. However, the utilization of such technologies requires continual professional development of teachers that would allow them to use these tools most effectively and adjust the teaching methods in order to embrace the new technological improvements.

The integration of digital technology skills would further allow learners of all age to develop skills in the future – including the immersive simulation learning practice. The emphasis on IT skills is critical in preparing the students for the workforce of tomorrow, where most careers will require digital literacy as a mandatory skill. Using these competences early in education via STEM activities does not only make students ready for future challenges but also makes access to the new learning modalities democratic. Yet, this approach calls for the need to focus on curriculum design to embed technology in such a way that it improves learning but without increasing the education gap among different social groups. The integration of these studies together with the NSM Makerspace activities suggests that, although gender has no significant differences in terms of learning practice, age and technology has a strong impact on learning environment of individual. Reviewing this, it can be suggested that, future learning environment should focus on the implemention of technology to improve immersive learning approach.

4.7.6 STEM Learning, Collaborative Flow, and Hands-on Learning in Thailand's Context

Ultimately, the study wanted to see how these concepts of STEM learning, collaborative flow, and hands-on learning (experiential and immersive learning) fit well within the context of Thailand and makerspace.

Exploring how these principles translate into the Thai educational context is crucial, especially considering the cultural and social nuances that can shape learning experiences. Specifically, the research intended to decipher how the components of flow and immersion, which are significant for experiential and hands-on learning, are realized in the specific context of a Thai makerspace. Flow as a state marked by total involvement and intensity in an activity and immersion as deep involvement and presence are important in developing the learning process. Understanding how such states are developed and maintained in thailand educational context offers interesting aspects of flexibility and success of these learning approaches in different cultures. The stir of STEM learning, collaborative flow, and hands-on learning is also found in many aspects of Thailand's educational system. The Thai Government has come up with strategic development plans aimed at inculcating 21st-century skills in Thai students, such as critical thinking, creativity, problem-solving, and collaboration, which are equally core skills nurtured in the effective STEM education (Office of the Education Council, 2017). The linking with the national educational aims and objectives emphasizes the importance of the study and hence, timeliness of understanding the interplay between flow, immersion, collaborative flow, and STEM learning in the Thai context. Concerning the development of educational policies, STEM learning can synchronize with knowledge production, which incorporates creative behavior among the learners (The Office of the Education Act 1999, amended in 2002). Revealing the pattern of interconnection and effect of these concepts on educational outcomes in makerspaces in Thailand provides an overview of both usability and potential benefits of these learning paradigms in development of the 21st-century skills.

When talking about the essence of flow experience and collaborative flow, the results of this research revealed that collaboration and flow experience come out as two themes linked in the makerspace activity. The general study of these links turned both wide and intensive and it revealed all subtleties of the interaction of individuals in the makerspace setting. Through the findings of this research, it can be noticed that collaboration happens through such activities as sharing the material with others, helping other people to do certain tasks and collaborating within the team. How ordinary activities can turn into a collective flow experience of creativity and innovation is particularly enlightening.

Two factors, including supporting and collaborating within a group, have been referred to in the past literature, for instance, Abrams (2018) and Cherney (2011). These landmarking works have set a strong platform for interpreting the complexities of team co-working, illuminating the multidimensional character of group interactions. This literature proposed that working as a team not only improves the skill of cooperation but also creates a critical thinking. This is a critical takeaway, underscoring the importance of a collaborative environment in fostering not just cooperation but also a heightened level of creative thinking.

Furthermore, the findings of this study are also associated with flow learning. Three of the critical statements associated with flow experience (which were strongly agreed upon by the respondents) included "The Enjoy Makerspace activities captured my attention", "I found the activities interesting", and "I knew what I wanted to achieve". These responses, in my opinion, are indicative of a highly engaged and motivated participant group, which bodes well for the overall effectiveness of makerspace activities in promoting learning. These statements suggested that makerspace has been providing activities that could capture the respondent's attention. There was clarity (as the respondents knew what they wanted to achieve), which is important in the context of promoting flow experience. The alignment of personal goals with the activities at hand is, I believe, a crucial element in achieving a state of flow, thereby enhancing the learning experience.

Hence, the key themes that could categorise the collaborative flow experience as being capable of working in a member team – which, according to Ellenbogen et al. (2004), includes a member of 4 to 5. In my view, this optimal team size is a pivotal finding, emphasising the balance between having enough diversity of ideas while maintaining a manageable group dynamic. Having a member of 4 to 5 in a group can ensure that the team collaboration is effective, contributing to effective student learning. This, I contend, can serve as a guiding principle for educators and facilitators in structured group activities in makerspaces, aiming for the most conducive environment for collaboration and flow experience.

Furthermore, the findings also suggested that working within a team can contribute to increased engagement among the learner's group. This is a pivotal observation as it reinforces the notion that a collaborative environment is conducive to fostering engagement and active participation among learners. In my perspective, the synergy created within a team setting significantly augments the learning experience, offering a myriad of perspectives and ideas that can be mutually beneficial. Moreover, the findings of this study also explored the differences in the engagement level and cooperation level of the children and parents. For instance, in terms of children, it was observed that the children were willing to engage with their instructors and parents and were more confident in their creation – specifically within their group. It is noteworthy to mention the transformative impact these activities had on the children's self-esteem and self-expression. From my standpoint, witnessing this marked transition from reticence to assertiveness highlights the empowering potential of makerspace activities, especially when conducted in a supportive group setting.

Furthermore, they also expressed enjoyment through their excited faces. They confirmed that these activities contributed to answering questions from instructors with confidence. I interpret these visible signs of joy and the children's newfound ability to communicate assertively as indicative of a successful intervention where the learning environment is effectively catering to the developmental needs of the participants. This was a significant improvement among the children, compared to prior to being engaged in the activities – which showed that they were shy and lacked confidence in expressing themselves. In reflecting on this change, I am inclined to believe that such a shift in demeanour and confidence level is not just a testament to the efficacy of the makerspace activities but also a call to action for educators and parents to actively seek and incorporate similar interactive and collaborative learning opportunities in the educational journey of children.

To operationalise this plan, a number of initiatives have been launched, with an emphasis on hands-on learning and collaborative flow in the context of STEM education. These initiatives are particularly aimed at fostering environments where students can experience flow and immersion, thereby deepening their engagement and enhancing their learning experiences. The state of flow, a concept central to this study, is achieved when students are fully immersed and find the right balance between the challenge of the task and their skill level, leading to heightened concentration and enjoyment. Similarly, immersion in the learning process is crucial for students to internalise concepts and apply theoretical knowledge in practical scenarios, further strengthening their critical thinking and problem-solving skills.

This includes the establishment of Innovation Learning Centres or makerspaces across the country, where students can engage in creative projects using digital fabrication tools such as 3D printers, CNC machines, and electronics (Office of the Basic Education Commission, 2022). The facilitation of these devices across each of the spaces can ensure and foster the right learning environment for the learners and makers. These spaces are designed to be hubs of innovation and learning, where the principles of flow and immersion are integral to the educational approach. Students in these environments are encouraged to explore, experiment, and collaborate, fostering a sense of community and shared learning, which is conducive to experiencing collaborative flow. Tackling real-world problems, the participants in the STEM learning program through the use of technical proficiency, collaborative flow, and enjoyment process – were capable of fostering themselves in an expert learning environment compared to others.

This ability to navigate and address complex issues is enhanced by the immersive nature of the learning experiences and the opportunities to enter a state of flow where students are most receptive to acquiring new knowledge and skills. The interplay between flow, immersion, and collaborative learning in these maker spaces creates a dynamic and enriching learning ecosystem, positioning students at the forefront of STEM education. The integration of collaborative flow is even more significant in the context of engagement and interest of the children, whereby I observed a noteworthy synergy. In my understanding, the incorporation of both collaborative elements and individual flow experiences can create a fertile ground for enriched learning and exploration. It was seen that flow learning and flow experience contribute to increased excitement about the activity, as well as increased cooperation with the instructors. In light of these observations, I am led to believe that a harmonious balance between collaboration and individual flow can significantly enhance the interactive dynamic between the learners and the instructors. This balance, in my opinion, fosters a mutually enriching environment where curiosity is ignited, and learning becomes a shared journey.

Moreover, to promote family learning, not only is the Maker-Space programme, but science museums and knowledge parks in Thailand have curated the exhibition of family-friendly interactive learning programs, encouraging participants of all age groups. Some examples of these include the National Science Museum (NSM), The Rama IX Park, and others that nurture collaborative learning practices within families, fostering an appreciation for STEM subjects – science, technology, engineering, and mathematics. The effectiveness of STEM learning and the adaptation of makerspace has been affirmed to influence individual behaviour and learning experience, as stated in the literature by Keeratipibul et al. (2022). The findings by Keeratipibul et al. (2022) affirmed that the makerspace environment and hands-on learning were effective in improving problem-solving skills, creativity, and team collaboration. The findings were also supported in the literature by Pooncharoen et al. (2021), which exhibited how science museums facilitated family learning and enhanced engagement and understanding of science concepts among visitors.

Despite positive strides in promoting STEM learning, collaborative flow, and hands-on learning, some challenges still need to be addressed in this context. Some of these potential challenges are recognised in the literature. For instance, the study by Kerdcharoen et al. (2021) found that some regions in Thailand, like the rural regions, need more resources that facilitate effective STEM learning. Similarly, the paper by Sukwittinant et al. (2022) also furthered this, stating that the variability in family learning practices may influence how families react and, therefore, could ideally skew the learning process. Others became apparent throughout this research, for example, the potential exclusion or self-exclusion of families whose parents are not as confident in their own STEM knowledge and making skills from the makerspace and the lack of interaction between parents and children in some families. These challenges mean that while the impact of the makerspace may be similar for children on their own, they lose the benefit of family-leaning contexts. Overcoming these challenges would require effective and collaborative flow and, therefore, continuous investment in educational infrastructure and teachers' professional development to create an informed practice about the STEM learning program. Additionally, innovative strategies to engage families in the learning process, such as parent workshops or family-focused events, could further promote family learning and engagement in STEM.

Therefore, the context of Thailand presents an exciting landscape for STEM learning, collaborative flow, and hands-on learning. With the continued commitment of government, educators, and the community, there is potential to foster these educational practices further, ultimately nurturing a future generation of creative, innovative, and collaborative problem solvers. In connection with makerspace ideas and prospects for Thailand, it should be mentioned that makerspace concept is a cornerstone of learn-by-doing, STEM education, and collaborative flow, especially in the context of Thailand's education. A makerspace provides a collaborative environment for students to experiment, learn, and create with different tools and materials. It offers learners an atmosphere that fosters creativity, teamwork, and critical thinking, which are the main elements of STEM education. Makerspaces are the gateway of STEM education in Thailand. As stated earlier, the government has supported the creation of Innovation Learning Centres also termed as makerspaces throughout the country thereby making these centres a critical component of their approach. Such students also develop a collaborative flow, which improves their participation, enjoyment, and learning outcomes, and finally, enables them to acquire 21st-century skills.

In the same way, maker spaces can work as centres of family learning activities thus stretching their reach outside the normal school environment. Through interactive projects, the families can interact and create a culture of STEM in the family members of all ages. As a result, makerspaces in Thailand are not just learning areas, but rather, they become communal learning spaces that gather people, communities, and ideas, creating a culture of creativity, innovation, and collaboration. Hence, the inclusion of makerspaces within the Thai educational milieu is an important step towards the future, where the learning of STEM, hands-on experiences, and collaborative flow are considered as the normal and not the exception, and they open promising implications for the Thai as well as non-Thai educational practices.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion of The Study

In this research study, the researcher intends to answer five key questions. These questions include – (a) how is immersion experienced in the NSM Enjoy Makerspace? (b) How do family visitors learn from the NSM Enjoy Makerspace activity? (c) What factors encourage family visitors to learn with the NSM Enjoy Makerspace activity? (d) What Family visitors motivations, knowledge skills, inspiration, and creativity are derived from NSM Enjoy Makerspace? And (e) what are the family visitors learning outcomes as a maker through NSM Enjoy Makerspace? This chapter intends to answer these research questions after delving into the summary of this overall research thesis.

The National Science Museum (NSM) Makerspace is a destination to create intriguing educational experiences that contribute to the development of skills, imagination, and creativity among the participants, facilitating scientific tools and materials and engaging in scientific, technological, engineering, and mathematical subjects and concepts. The maker movement, such as that adopted by NSM Makerspace, emphasises the development of a workspace trend that is dedicated to intricately linking the learning programme with STEM learning and enhancing the proponents of opportunity to democratise education and empower learners with knowledge and skills. The rationale for the integration of the NSM Makerspace programme further enhances experiential learning, which allows the creation of knowledge through the transformation of experience into education.

The NSM makerspace further integrates family learning practices, improving the bond between the family members and the participants, such as the children. Hence, it can be understood that the NSM Makerspace Activity integrates concepts combining factors-STEM learning, family learning, and experiential learning – as a means of enhancing knowledge and skills. Hence, in exploring these concepts, this study emphasises investigating the process of family visitors becoming makers in the NSM Enjoy Makerspace, particularly at NSM, Thailand. The objectives of this study are:

1. To develop family visitors learning through NSM, Enjoy Makerspace activities at the National Science Museum, Thailand.
2. To describe the factors that encourage family visitors to learn as a maker through NSM Enjoy Makerspace
3. To study family visitors learning outcomes through NSM Enjoy Makerspace
4. To explore family visitors motivation, knowledge, skills, inspiration, and creativity from NSM Enjoy Makerspace via the focus on family learning, experiential learning, flow and immersion and STEM learning.

The significance of the study aligns towards investigating this research to identify and describe factors that can encourage all-age family visitor learning within the NSM Enjoy Makerspace activities, which allows identifying benefits of museum staff, curators, museum educational teams, and external educators.

The literature review of this study provides an in-depth examination of various institutional agents, policies, and concepts related to NSM, particularly in Thailand. The use of NSM and the concepts of makerspace program contributes to the universal design influencing the STEM learning process. One of the key principles associated with the development program is associated with the sustainable development goal (SDG) – Goal 4, associated with ensuring quality education for all. In line with SDG goal 4, the Thai Vision 2037, the three principles followed by Thailand's vision for 2037 include security, prosperity, and sustainability. Each of these aspects surrounds ensuring the six elements of educational well-being, including citizen well-being, economic growth, talent development, equity and equality, sustainability of its resources, and accessibility and government efficiency. The Thai Vision 2037 further emphasises transforming their conventional educational approach, such as - formal, non-formal, and informal education approaches, ensuring enhanced educational approach, including enabling learners to study independently based on their interests, potential, and opportunities.

Furthermore, empirical research concepts of learning explored in this literature suggest that learning activities such as makerspace activities can contribute to active learning education, cooperative learning and family involvement, and enhanced innovation skills. Considering such, however, there exists a key research gap surrounding the NSM Enjoy Makerspace activity – with the specific gap being that there is a lack of research that emphasises studying the family and experiential learning together, particularly those that adopt the use of multi-method, including observations, interviews, and close-ended survey questionnaires. Considering such, the findings of the literature review also indicate that there is a lack of research surrounding the exploration of the effectiveness of the makerspace program in Bangkok, Thailand, and in particular – across the National Science Museum. Hence, considering such, a multi-method approach has been implemented in this thesis to explore how the NSM makerspace activity rejuvenates the definition of learning. Hence, all in all, the literature review delves into empirical research papers that explore the cognitive impact of active learning, group learning as a collaborative strategy, and cooperative learning in a family setting. The study aligns with the concept of active learning, which allows learners to pursue learning through discovery, processing, applying, and synthesising information together. The cognitive impact of active learning can improve the levels of processing of information and allow faster recollection of information.

This study adopts the use of a multi-method approach as the methodological approach to meeting the research aim and objectives. The findings of this study are associated with answering the research question – (a) How do family visitors learn from the NSM enjoy makerspace activity? (b) What factors encourage family visitor learning with the NSM Enjoy Makerspace activity? (c) What Family visitors motivations, knowledge skills, inspiration, and creativity are derived from NSM Enjoy Makerspace? (d) What are the family visitors learning outcomes as a maker through NSM Enjoy Makerspace? Considering the research questions of this study, the three methodological approaches for data collection include (a) the process of primary observations, (b) collecting qualitative interviews, and (c) collecting quantitative data through close-ended surveys. Prior to performing the research, a pilot study was conducted with four families. Following the conduct of the pilot study, the actualised study comprised an observational study, close-ended questionnaires to parents and children, and interviews. Therefore, the study was divided into three stages, including Stage 1 – pre-participating in enjoy makerspace using engagement observation (EO); Stage 2 – during participation, including engagement observation, skill observation, and motivation observation; and Stage 3 – post-participation in Enjoy Maker space (EMS). The data for the study is analysed using descriptive statistics analysis, content analysis, numerical analysis such as correlation, documentary analysis, and photographic analysis. Each analysis procures a range of findings associated with the development of an understanding of how the NSM's EMS program can affect learning and, therefore, influence the ideation of skills, motivation, and engagement levels of the participants. Based on the methodology employed, the findings of the study are summarised as follows.

The primary findings of this study, revolving around the Enjoy Makerspace Syringe Rocket activity, illustrate the substantial contributions of makerspaces to various positive learning outcomes and experiences for participants. These findings align with the existing literature, encompassing active learning education, group learning as a collaborative strategy, and cooperative learning involving family engagement. In performing the Enjoy Makerspace Syringe Rocket Activity, the NSM makerspace accentuates how makerspaces more generally contribute to a wide range of positive learning outcomes and experiences for participants. One of the key findings observed through the observational methodology was associated with the Makerspace Syringe Rocket Activity, which indicated that the collaborative learning environment encouraged family involvement, providing a supportive and collaborative learning environment. In other words, the combination of family involvement with a supportive and collaborative learning environment prompted open discussions with instructors and assistants, as the makerspace activity allowed children, as well as their parents, to actively participate in the learning process, assisting and guiding children in their projects. Hence, these findings indicate that makerspaces should incorporate active, group, and cooperative learning to enhance the learning experience of participants, which provides an environment that encourages the active participation of family members and promotes a collaborative learning environment. Combining this with the concept of collaborative flow, the dynamic interaction between the families and children can allow a further progression towards the children's learning capabilities. While the original concept of collaborative flow integrates the dynamic interaction between students, teachers, educators, and others – the application of collaborative flow in the context of this study primarily revolves around the parents and their children. However, as the activity of makerspace acted as structured support for the development of vital skills such as problem- solving, communication, teamwork, and creative thinking, it allowed participants to acquire new skills in invention and tool usage while building their confidence by overcoming challenges and obstacles.

In the context of collaborative flow learning, it was observed that children who were also engaged in the makerspace activities were highly confidence and reciprocated strongly to the existing activities. This observation underscores the intrinsic motivation and eagerness children exhibit when immersed in an environment that nurtures creativity and collaboration. From my perspective, such a vibrant and dynamic atmosphere significantly contributes to fostering a deep and enduring love for learning. The findings observed in this study showed that, during the activity, children were highly energetic and participated in the study. Nevertheless, apart from all other actions and activities, the kids were very excited about making their own projects – and were also ready to ask and talk about questions to leaders and helpers. In my view, the situation is a manifestation of the natural curiosity that children possess and which, if left to thrive, could result in great learning and critical thinking.

The results further revealed that the group did interact with the environment and make choices of material and use tools to enrich their learning. To me, this speaks of the children's developing agency and flexibility, two crucial competencies required to negotiate the constantly shifting seas of knowledge and technology. Moreover, the results of this study also revealed that adult observations also showed significant differences. With respect to adults, it revealed the fact that the adults were likely to focus on leading of the kids in the project and also asking questions and sharing what the kids could learn further. I find this shift in parental engagement particularly encouraging, as it suggests a move towards a more collaborative and dialogic approach to learning, where the exchange of ideas between parent and child is valued and nurtured. In addition to that, the parents were also including other parents and instructors in their conversation while encouraging their children to think, answer questions, and solve problems. This communal approach to problem-solving and learning, in my view, enriches the learning experience, creating a supportive network of diverse perspectives and insights. Hence, not only the students but furthermore, the enthusiasm was also prominent in the context of the parents. Observing this shared enthusiasm between parents and children, I am optimistic about the potential of such collaborative learning environments in bridging generational gaps in understanding and fostering mutual respect and learning.

Furthermore, in terms of collaboration, in this study, it was found that collaboration emerged from the aspects of sharing materials, helping others doing the tasks, and working in a team. These elements of collaboration, as revealed by the study, are foundational to creating a harmonious and productive learning environment. In my assessment, the willingness to share and support peers is reflective of a sense of community and mutual respect within the learning space, which is crucial for fostering positive learning experiences. Following the findings of this study, the flow experiences could be developed along with the collaborative flow – which could be measured based on totally capturing my attention, ensuring activities in interesting activities, and knowing what to achieve. I find it compelling that the study intricately links flow experience with the collaborative flow, thereby highlighting the symbiotic relationship between individual engagement and collective synergy. Ensuring that activities are captivating and align with individual goals is, in my view, fundamental in cultivating flow experiences. This showed that another key factor associated with the flow experience and collaboration was forgetting about the progress of time. This observation resonates with me as it underscores the immersive nature of such experiences, where learners are so deeply engaged that they lose track of time. In my opinion, this is indicative of the transformative potential of collaborative learning environments, where individuals are not just absorbing knowledge but are actively and joyfully immersed in the process of learning and creating.

Yet for replicability of such experience, it is necessary to make sure that the makerspace programmes provide a conducive environment for families to share learning experiences, which can lead to the development of crucial skills such as problem- solving, communication, teamwork, and creative thinking. This may also enable the teachers to judiciously adjust the tasks and challenges in line with the learner's current ability and also to give immediate feedback, which could enhance interactive and inventive learning experience.

However, the major problem of replicating is the flow experience. This becomes a subtle barrier, because maintaining a uniform flow state requires a fine balance of challenge and skill, something that can differ widely from individual to individual. Identifying and dealing with this issue is critical in leveraging the effects of Makerspaces on learning processes. The results of this research also supported that flow experience and collaborative flow, incorporates the requirement of engagement – the Makerspaces must ensure that they are able to keep the audiences engaged, excited, and entertained while the activity is taking place. The researcher concurs with this observation and emphasises the importance of curating activities that are not only intellectually stimulating but also resonate with the participant's interests and passions. This, in the author's opinion, is crucial for sustaining engagement and fostering a genuine love for learning. Among the children, though this could be attained, it is challenging due to their nature of quickly being bored. Addressing the varying attention spans and interests of children adds a layer of complexity to this challenge. In the author's view, this calls for a dynamic and adaptable approach, where activities are continuously evolved and tailored to meet the diverse needs and preferences of the children. Creating an environment that is both stimulating and flexible is, researchers believe, essential for maintaining the engagement and curiosity of young learners. Hence, it can be affirmed that incorporating family participation in collaborative learning has also been demonstrated to increase learning outcomes, particularly in complicated areas such as science. Family engagement in the educational process may be recognised as a scientific learning process, and children aged 5 to 6 are predicted to develop in complicated topics such as science. Similarly, cooperative and collaborative learning has been found to improve several elements of students' lives, including self-image, study habits, and subject satisfaction.

One of the key terminologies associated with the concept of learning in a familial environment was - active learning education, which, as defined in the literature, is a model of "instruction" that allows learners to pursue learning through discovery, processing, applying, and synthesising information together (Bloom, 1956). The concept of active learning, when combined with engaging content, reflective behaviour, and ideal objectives, can result in a more meaningful experience for the learner (Cherney, 2011) and can improve the levels of processing of information, allowing faster recollection of information (Craik and Lockhart, 1972). Other literature has also ascertained that active learning has been adopted as a pedagogical paradigm that merges learner-centred teaching behaviour and patterns with active learning, creating a "meaning-making" experience for the student/learner (Cherney, 2011). In addition to the past findings on the relevance of makerspaces, the findings of this study further showed that makerspaces encourage hands-on learning experiences and foster problem-solving, communication, teamwork, and creative thinking skills.

Furthermore, the outcomes further suggest that these NSM makerspace activities can encourage improved learning through the integration of flow learning, primarily based on immersion and active learning processes. This also contributes to creating an environment that ensures "learning by doing" and promotes a sense of curiosity and exploration among the learners. Makerspaces serve as a hub for collaborative learning, where individuals can share knowledge, brainstorm ideas, and solve problems together, thereby enhancing their learning experience. In achieving active learning through makerspace activities, participants of all age groups are engaged in meaningful learning experiences. They are motivated to expand their knowledge and skills in science, invention, and creativity. The hands-on nature of these activities helps in developing critical thinking, problem-solving, and communication skills, which are essential for the 21st century learner. These findings echo the literature's emphasis on the importance of active learning in creating an effective educational environment. Hence, collaborative and cooperative learning environments can be used interchangeably in pedagogical domains. This interchangeability provides educators with the flexibility to adapt teaching methods and strategies to cater to the diverse needs of learners. This concept can be applied to teach lifelong skills, motivation, and teamwork. In addition, incorporating real-world applications and challenges in makerspace activities can make learning more relevant and interesting for students, thus fostering a deeper understanding of the subject matter. Family involvement in cooperative learning and flow can ensure an improved learning process. Involving families in the learning process not only provides support and encouragement to the learners but also creates a conducive learning environment at home. This, in turn, helps in reinforcing the concepts learned and in developing a positive attitude towards learning. Family member involvement can be acknowledged as a scientific learning process for children aged five to six years old. This early introduction to active and cooperative learning can lay a strong foundation for the child's future learning journey, instilling in them a love for learning and an inquisitive mindset. Children with family involvement are expected to improve their understanding of complex subjects such as science. Moreover, the family's role in facilitating and supporting the child's learning experiences contributes to the development of a lifelong learner who is adaptive, innovative, and capable of overcoming challenges.

Moreover, the primary findings of this study are consistent with the literature on group learning as a collaborative learning strategy. The makerspace environment promotes a supportive and collaborative atmosphere, enabling interaction and collaboration among family members and with instructors and assistants (Dillenbourg, 1999). As defined in the literature proposed by Bonwell and Eison (1991), collaborative or cooperative learning in a small group of 2 to 5 members can increase student activity. It is used to train lifelong skills, motivation, and teamwork. This was supported by Wyk and Haffeejee (2017), and this has been found to enhance student retention, social skills, and good relationships with students from different cultural backgrounds. The literature also emphasizes on the advantages of collaborative learning that include teaching the learners how to relate with other students, improving their interpersonal relationships and also helping them have positive relationships with other students from different cultural backgrounds. Consistent with the review of literature, the major research findings of this study indicated that through observation and interview it was discovered that learning both in family environments and through the active participation of the learner, with assistance from other children can enhance children's learning experiences. This is consistent with the past, like, research by Ulutas and Kanak (2018) which validated the findings in a 5 to 6 years old children context. The literature highlighted that, in these formative years, family engagement is critical for developing a solid foundation for language, physical dexterity, social understanding, and emotional development that children will utilise throughout their lives. The findings of the study have been further accentuated in the research by Henderson and Martin (2004) and Rego et al. (2018), indicating the positive effects of family involvement on children's academic performance and self-image, study habits, and satisfaction with the subject.

Additional insights associated with the findings of this thesis go along with STEM learning. Herein, it can be accentuated that NSM activities tend to provide opportunities for participants to understand and apply science, technology, engineering, and mathematics concepts, specifically by the facilitation of learning and understanding of scientific principles and supporting the development of basic STEM knowledge and skills. Makerspaces enable participants to experience the enjoyable aspects of the decoration process, applying mathematical skills for creative purposes. They enjoy makerspace activities that exemplify the integration of active learning, group learning, and cooperative learning with family involvement. The collaborative nature of the activity allows participants to experience the enjoyable aspects of decoration processes and apply mathematical and scientific skills for consensual and complementary development. They also provide fun, hands-on learning experiences that motivate participants to expand their knowledge and skills in science, invention, and creativity.

This project concluded that makerspaces led to an influence for continued learning and exploration, thus, developing an interest in STEM subjects and projects. The science and technology subjects can still be linked to the Education Sustainable Development (ESD) program. The ESD program in this instance is of significant importance in showing the connections between constructivism theory, Education for Sustainable Development (ESD) and the Makerspace educational model. Constructivist theory claims that knowledge is dynamic and that people create new knowledge depending on their past experiences, social, language and cultural interaction, as well as local environment and circumstances (Piaget, 1950). Makerspaces are constructivist by nature in that they offer a chance for the learners to make and build their knowledge through participant and collaboration.

Additionally, the literature by Leicht et al. (2020) emphasizes that the use of ESG in the education system will enable the current generation to empower and prepare the current and future generations for their needs in a balanced integrated way to develop the economic, social and environmental aspects of sustainable development. Makerspaces also promote documentation and sharing. Participants can play with, photograph or film the activity, and then publish their creations and experiences in a variety of media and other venues. The practice would be an excellent way to keep memories and serve as an example of what others should do while engaging in makerspace activities. Therefore, makerspaces are critical elements in promoting diverse learning outcomes and promoting a conducive and inclusive environment of skill development, family engagement, and the advocacy of STEM subjects. These findings can be summarised based on the following figure below:

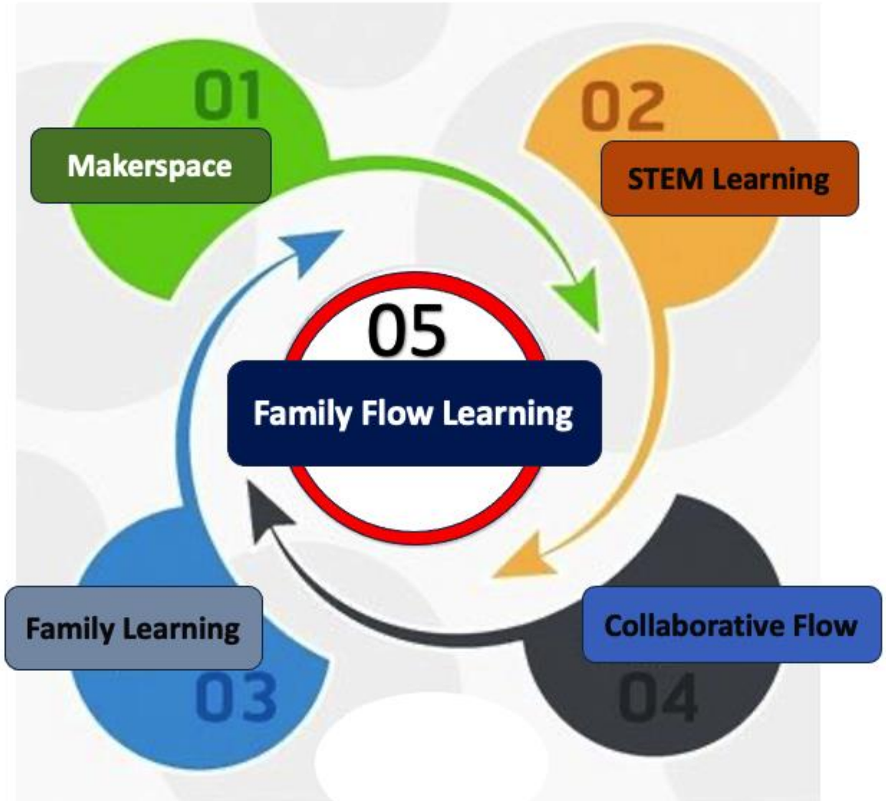

Figure 28: Findings of the Study – Summary

The findings of this research study have been effectively capable of answering all the 5 research questions proposed in this thesis. First, the question "How is immersion experienced in the NSM Enjoy Makerspace?" intended to understand experience-based factors emerging from the NSM Enjoy Makerspace activity. The findings of this thesis suggested that immersion in the NSM Enjoy Makerspace is experienced through 3 key elements, including (i) active learning education, (ii) group/family learning, and (iii) cooperative/collaborative learning experience. The participants of this study, including family visitors and groups, had a high engagement rate in hands-on learning experiences, which was further supported through a collaborative and supportive atmosphere within the makerspace. The findings of this study confirmed that a collaborative and supportive atmosphere, for instance, the presence of parents during activities such as making the rocket, encouraged interaction and fostered a sense of immersion. The immersion significantly impacted the enjoyment of the creative process, application of mathematical and scientific skills, development of problem-solving capabilities, and teamwork. Second, the question “How do family visitors learn from the NSM Enjoy Makerspace activity?” is intended to review the different combinations of activities contributing to learning capabilities.

The findings of this study showed that the makerspace environment provided an opportunity for the participants, including parents and children, to construct knowledge through hands-on experiences and effective collaboration. The findings further confirmed that the presence of family members such as parents mediated a significant impact on children's learning process. Children were also found to learn faster and more actively with assistance and guidance from their parents. The family flow figure presented above showcases that, the overall findings can be applied in the context of research community, museum authorities/trainers and government's initiatives in improving/immersing the family flow learning via STEM. In terms of the findings of this study, the family learning experience in NSM makerspace guides the readers towards developing a nuanced understanding of how to improve the makerspace learning practice. The findings combine the 4 key factors, makerspace, STEM learing, family learning, and collaborative flow practices. The research was conducted in the context of Thailand, and more specifically, in the context of Thai parentsand childrens – which can provide valuable insights in terms of the family management in makerspace activities. The subjects under study, including STEM subjects fosters a culture of collaboration and knowledge-sharing within the research community and among differen stakeholders. Similarly, in terms of museum authorities and trainers – these stakeholder groups can use the findings of this study as a mean/source of information to collaborate with researchers, providing real-world insights and challenges that can inform future studies. In addition to that, government initiatives can be developed, which leverages this collaborative approach to educating the children, allowing to design policies that are responsive to the practical needs of museums and makerspaces. This interconnectedness between research, practice, and policy ensures that advancements in family learning experiences within STEM, which is no only limited to being a research-driven approach, but also grounded in the practical considerations and challenges faced by those implementing such programs.

Hence, this study suggests that a collaborative learning environment allows students to develop essential skills and ensure active learning among children about complex subjects such as science, mathematics, and technology. Similarly, the third question of this study is – "What factors encourage family visitors to learn with the NSM Enjoy Makerspace activity?" The findings of this study showed that there are 3 key factors that encourage family visitors to learn with the NSM Enjoy Makerspace activities, including (a) a supportive learning environment, (b) family involvement and engagement, and (c) creative process development. Herein, the findings of this study showed that the makerspace activity acts as a space whereby family members can bond over shared learning experiences. This can promote the development of vital skills for the growth of the children, such as problem-solving, communication, teamwork, and creative thinking. Recognising the potential of makerspace activities in enhancing the knowledge and skills of the children can also be, therefore, deduced as an encouraging factor for families to learn with the NSM Enjoy Makerspace activity.

The fourth question of this research is "What Family visitors motivations, knowledge skills, inspiration, and creativity are derived from NSM Enjoy Makerspace?" This question is intended to explore the resultant effect of NSM Enjoy Makerspace activities on the learning experiences of family visitors. The findings of this study also confirmed that active engagement was a key factor that derives strong motivation, knowledge, skills, and inspiration.

The collaborative and cooperative learning environment across the NSM Makerspace activities allows problem-solving, communication, and teamwork. The participants, primarily the children, were motivated to expand their knowledge and skills across each of the STEM subjects, with the presence of active learning, which can further create enjoyable and educational learning. This also grants the recommendation that it is important for the NSM Makerspace Activities and educational institutions to ensure that the learning curricula are primarily interesting and entertaining. Finally, the last question for this research study was "What are the family visitors learning outcomes as a maker through NSM Enjoy Makerspace?" The findings of this study showed that, combinedly, the key learnings for the family visitors through NSM Enjoy Makerspace activity included problem-solving, communication, teamwork, and creative thinking. However, these stand from the perspective of the growth of the participants, in particular, the children. However, there are also other benefits that were recognised from the study. Participating in NSM Makerspace Activities can enhance individual confidence among the students when overcoming challenging obstacles and projects in real life. Similarly, participation can also encourage improved family bonding due to a high focus on family engagement in the NSM Makerspace activities. Further findings also showed that participation in NSM Makerspace activities could contribute to the development of education-sustainable development programs and their goals in further significance.

From the extensive research undertaken here, I have explored a few opinions on what are the main ingredients of family learning in STEM. As family learning is amongst young and old members of the family, it is important to evaluate my findings into something creative, something joyful or something easier for people to comprehend, connect with and ultimately understand. The brightest colors in the family learning picture within the realm of STEM are not only collaboration learning, experiential learning, and flow and immersion but something else – that is, something deeply transformational and greatly richer. Picture, for example, painting these ideas in a more imaginative fashion, in a palette that is not bound within the traditional lines. In this newly painted scenario, collaborative learning would be lovingly called "The Symphony of Shared Discovery". In this symphony, each member of the family's input – whether a question, a revelation, or a mere curiosity – becomes a note in a grand musical composition. This tune is not only about individual involvement; it is about harmony, reconciliation, and attractiveness of collective involvement, where every sound, no matter its tone, brings a distinctive value to the educational choir.

In contrast, experiential learning becomes "The Playground of Practical Magic". This is not just a playground; it is a place where hands-on activities make science, technology, engineering and math come alive. In this case, abstract ideas are not simply perceived, they are felt, manipulated, and witnessed in action, thereby transforming the intangible into tangible experiences that do more than provoke interest, they inspire the imagination. It is a domain where learning goes beyond the ordinary, where learners wear the crown of a magician, where every experiment and project becomes an act of miracle revealing the concealed mysteries of the universe in the most exciting ways.

Then, flow and immersion merge to create what one might call "The Dance of Deep Engagement". This process doesn't aim to absorb, but rather to place teaching-learning in another dimension where learners lose concept of time and the rest of the world. A child creating a model of the solar system and their family coding a simple game do not notice how much time goes by while they excitedly work together. This dance is where puzzles of logic, some water and oil experiments or spaghetti bridge challenges take learner's attention all the way in. In this world, activities such as programming a robot to negotiate a maze, putting a circuit together to illuminate an LED, or even the group thinking to solve an environmental problem become more than mere chores; they are doors to a flow state. When a parent and a child argue about the best way to make a paper plane that will fly the farthest, or play with various materials to learn what they do, they are not only learning about aerodynamics or materials science— they are sharing a moment of close connection and involvement. Every trial, every error, and every improvement is a single move of this dance, a process that keeps both the mind and the soul wrapped completely in the enchantment of learning- an ongoing fascination with possibilities. Therefore, the dance of deep engagement, illustrated in such bright examples, is that which makes the integration of flow and immersion from a concept to a real experience. This is the place of the application of theoretical knowledge that occurs at the most attractive manner, but not just individual success, but creating collective astonishment and success. When the journey through the complexities of science and technology becomes a vibrant adventure that tickles the mind and instills the thirst for discovery, this is the core of transformative learning in STEM.
This technique improves the learning procedure and makes students feel spiritually united since they start their adventure into the unknown region as problem-solving and mystery-smiling challenges.

This complex mix of elements: The Symphony of Shared Discovery, The Playground of Practical Magic, and The Dance of Deep Engagement is the model for family learning in STEM. Together, they create a stimulating and interactive learning context that is driven by inquiry, imagination, and analysis. When these creatively redesigned modules are approved as part of the initiative, the educators and program developers can develop STEM learning opportunities that go far beyond the traditional learning realm, providing parents not just knowledge, but an intense joy and a great involvement. This attitude creates an environment of pleasure of learning and investigation in each experiment, project, and question, and all this together embodies friendly and live atmosphere, which starts guiding whole families on a way of discovery and joint growing. In this case, STEM learning becomes a world of possibilities and delight, a path not only of academic accomplishments but of individual development, common understanding and the pleasure of knowledge that unites the families in the pursuit of learning and creativity.
Predict AI Score

5.2 Significance of the Findings and Recommendations from The Research

The target audience of the findings can be broken down into various key stakeholders. The first key stakeholder is the community. The community can use these spaces to encourage individuals to unite and create. Libraries can also use them to implement learning programs related to science, technology, engineering, and math (STEM). In addition to being superlative and subjective resources for individuals, these spaces allow people to explore different creative paths that highlight the intersection of technology, arts, and science. Also, many libraries are drawn to this type of programming due to the potential to teach students the necessary skills for success in the workplace. According to Saunders et al. (2019), a key skill they believe is gained through programming in a maker space is design thinking. This open-ended approach to problem-solving is often messy and can help them create innovative ideas. These skills can be developed through various types of makerspaces, such as those equipped with high-tech equipment, such as 3D printers and software. On the other hand, they can also be developed in less advanced settings, such as those made up of art supplies.

Secondly, the museum itself, for instance, apart from serving as personal superlative and subjective resources, museums, and libraries may use these areas to create educational programmes that complement the courses on these topics. They can be tailored to their users' different age groups and abilities. For instance, these spaces can be used by college students looking to develop new skills or adults looking to improve their capabilities. Therefore, the findings and knowledge available in this study show that museum members can develop an improved approach to family learning and simultaneously develop a strong affinity for potential family visitors. This could also further develop into more complex makerspace projects, targeting other audiences. Thirdly, the academic division. The findings from this study would amplify the importance of makerspace learning tools in education. Therefore, academics can use this as a benchmark to further study Makerspace in other areas and fields. Lastly, from a personal perspective, this research would add much knowledge to the scholar, followed by the possible achievement of her doctorate. In addition to that, the learning practice also contributes to the improving the cooperative and collaborative practices, specifically by community building, academic divison, and other general practice. In the context of this study, the key practices, includes the following.

- Active Learning Strategies- The research practice involves adopting active learning approach in collaborating and cooperating between individuals, whereby students would participate in group activities through the comprehensive use of vivid content, role- play activities, and the annotation of objectives as the key role of these will be to enhance cognitive processing and retention.
- Collaborative Learning- The collaborative learning practice would emphasize in using small group practices that emphasizes on the kind of skills such as engagement, cooperation and drive to help a student learn for life. Furthermore, students were found to perform well when they work together on a project. This can also improve their social skills whereby, developing their communication skills, and their ability to value a diverse team are the outcomes.
- Adaptation to Local Community Needs- Makerspace activities and programs allows educatiomnal programs at makerspace to be linked with social, cultural, and inter-cultural activities – that can be tailored to fit with the local community education

programs, which further enhances highlights the need to develop localized programs that match the community's requirements.

- Family Involvement- The importance of the family involvement in building up learning process is extremely important, whereby offering classes and events that encompass family and school groups together can help learners with the process.
- Friendly and Collaborative Learning Environment- Finally, the implementation of family involvement allows striving to create spaces that can simultaneously facilitate these outcomes, whereby, it is crucial for the learning of children and learner, as well as the learning of the teachers to improve the STEM learning experience.

By incorporating active, group, and cooperative learning, makerspaces can enhance the learning experience of participants and foster emotional intelligence, promoting sustainable solutions at the local level. The findings from this study contribute to the growing literature on the importance of makerspaces in enhancing the learning experience and promoting sustainable development. Further recommendations to the NSM makerspace and other key significance of the findings are presented in the following points below.

- Implement active learning strategies- Incorporate active learning approaches into educational programs to improve participants learning experiences. Create activities that empower students to actively find, process, apply, and synthesise knowledge. To boost knowledge processing and retention, provide compelling content, encourage reflective behaviour, and provide explicit learning objectives.
- Create makerspaces to develop emotional intelligence and to offer a happy learning environment. Makerspaces help move people away from the edgy and fretful learner to the confident and energetic learner. Ensure that makerspaces are a welcoming space that promotes the participation of people from different backgrounds and makes learning accessible, an appreciation of the tools and facilities available, and instruction from teachers and group leaders.
- Encourage cooperation and cooperative learning- At educational settings, promote collaborative and cooperative learning approaches. Promote small group learning with 2 to 5 members to enhance student participation and develop long term skills,

motivation, and team work. Collaboration and flow are two factors that have been proved to enhance the students' retention, student–student interpersonal skills, and student–student positive interaction across different cultural backgrounds.

- Documentation and sharing: Participants should be encouraged to document and share their experiences and creations. Platforms or opportunities should be given for participants to archive memories and exhibit their work. This practice not only gives the participants an opportu¬nity to reflect on their learning but also motivates others to partici¬pate in similar activities thus promoting locally grown sus¬tainable solutions.
- Adapt curricula to the needs of the local community- Make sure that makerspace projects and educational programs comply with social, cultural, and intercultural activities of the local community. Link the curriculum with local community education programs and discover the unique needs and interests of the community. Although all community preferences may not be adaptable to makerspaces, it would be useful to see what families do want to do and how these activities could be adapted.
- Encourage family involvement - Appreciate the role of family participation in the learning process. Run programs and make activities that will promote families to visit makerspaces and assist learners. Promote family members and participants to work together and share their learning adventures.
- Establish a friendly and collaborative learning environment- Create a setting that promotes positive learning outcomes. Provide resources, facilities, and help to make learning easier and to inspire people to explore and create. Encourage participants, teachers, and group leaders to feel supported, encouraged, and collaborative.

5.3 Limitations of The Findings & Future Works

In doing this research, several limitations were identified, for the potential of developing future works. The limitations of this study, highlighted from a scope-perspective, sample perspective, and others are presented as follows.

- Limitation A- Firstly, this study was limited based on the scope of the study. The scope of the research emphasised on the National Science Museum (NSM). The research scope allowed the collection of data from specifically the selected institution, and this leads to the lack of richness of data that could be acquired from other educational institutions such as the Rama IX Park. This limits the findings of the thesis, which could limit the generalisability of the findings.

  - Future Work A- Based on the limitation a proposed, it can be stated that future research should focus on expanding the research in the broader context. For instance, the scope should expand in terms of other institutions such as the Rama IX Park or also utilising new institutions in new regions, such as that of ASEAN countries, or even other Asian countries. This can allow the expansion of the research into a broader domain.

- Limitation B- The second limitation of the research is the multi-method approach. The multi-method approach, although can eliminate the limitations associated with the mono-method, the findings of this study was time-constrained. Due to the increased time constraint, the multi-method is only recommended in the context that, the research method can only be used when there is adequate time available in performing the research.
  - Future Work B- Future work based on limitation B is that the research using multi-method, including multiple data collection strategies such as observation, close-ended questionnaire, and open-ended questionnaire should be used when there is adequate time available. Otherwise, a mixed-method or a mono-methodology approach should be adopted.
- Limitation C- The third limitation is the sample of the research. The sample of the research in this thesis comprises only a limited number of families involved, including a total of 23 responses from the parents, and children. The responses, therefore, can be limited – and the data could not be adequate in expanding in such a context. Furthermore, this also leads to a limited availability of rich data that could procure broader findings.
  - Future Work C- Based on limitation C of this research thesis, future research should consider a broader sample group that can ensure broader data being collected in the study. Considering such, future studies should adopt a broader sample group, and could also adopt a culturally different group to ensure the generalisability of the findings.

In reflection, a child who attended the makerspace activity enthusiastically remarked, ***“I never knew learning could be this fun; I built a robot and learned how science makes it move!”*** This innocent proclamation exemplifies the potential impact and boundless possibilities these learning environments can imbue, igniting a youthful spark toward science and creativity.

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APPENDICES

Appendix 1: National Strategy on Developing and Strengthening Human Capital

Key development guidelines	Details
1. Transforming Thai people's social values and culture	Changing Thai people's social values and culture by encouraging all social institutions to work together to instil desirable values and culture by: (1) embedding values and culture through responsible family management; and encouraging all social institutions to work together to instil desirable values and culture. (2) Integrating honesty, discipline, and moral and ethical standards through educational dissemination in schools. (3) strengthening religious institutions. (4) fostering values and culture by communities. (5) promoting positive values and culture by the business sector. (6) creating values and culture through the mass media. (7) encouraging voluntary spirit and social responsibility among Thai people.
2. Promoting human development at all stages of life	Promoting human development at all stages of life, including:

Key development guidelines	Details
	(1) pregnancy and early childhood periods with a focus on creating pregnancy preparedness among parents. (2) school-age or adolescence with a focus on developing moral standards, discipline, and learning skills in line with 21st century needs. (3) working-age population with a focus on enhancing skills and capacities to meet existing market demands. (4) older people focus on encouraging older people to become a part of a critical driving force for national growth.
3. Improving learning processes to accommodate changes in the 21st century	Improving learning processes to accommodate changes in the 21st century by encouraging lifelong learning and development of learning skills, which can be achieved by: (1) adjusting learning systems to promote necessary skill development. (2) developing modern teachers. (3) Improving educational management systems efficiency at all levels. (4) developing lifelong learning systems (5) creating national awareness of roles, responsibilities, and Thailand's position in Southeast Asia and the global community. (6) using digital platforms for enhancing learning system bases (7) creating educational systems to promote academic excellence at international levels.

Key development guidelines	Details
4. Realising multiple intelligences	Realising multiple intelligences by: (1) developing and promoting multiple intelligences from an early age via improved educational systems and the mass media. (2) creating career paths, working environments, and support systems that promote specific skills through various effective mechanisms. (3) attracting foreign experts and Thai citizens living abroad to assist in the technology and innovation development required for the country development.
5. Promoting conditions that encourage human capacity development	Promoting conditions that encourage human capacity development include: (1) enhancing well-being and happiness of Thai families. (2) promoting the involvement of public and private sectors, local administrative organisations, families, and communities in human capital development. (3) embedding and developing skills outside of the school. (4) developing database systems to facilitate human capital development.

(Source: National Strategy Secretariat Office, 2018: 8-10)

Appendix 2: 21st Century Skills (Trilling And Fadal, 2009)

1. Learning & innovation skills: learning to create together	2. Digital literacy skills: info - savy, media- flaunt, tech - tuned	3. Career & life skills: work ready, prepared for life
1.1 The knowledge & skills rainbow	2.1 Information literacy	3.1 Flexibility & Adaptability
1.2 Learning to learn & innovation	2.2 Media Literacy	3.2 Initiative & self - direction
1.3 Critical thinking and problem solving	2.3 ICT Literacy	3.3 Social & cross – cultural interaction
1.4 Communication & collaboration		3.4 Productivity & accountability
1.5 Creativity & innovation		3.5 Leadership & responsibility

(Source: Trilling and Fadal (2009)

Appendix 3: 21st Century Skills (Adapt For Partnership)

1. Learning and innovation skills	2. Digital Literacy Skills	3. Career and Life Skills
1.1 Knowledge and skills 1.2 Problem Solving 1.3 Communication 1.4 Collaboration 1.5 Creativity Skill	2.1 Information Literacy 2.2 Technology Literacy	3.1 Flexibility and Adaptability 3.2 Self-Direction 3.3 Social Skills 3.4 Productivity 3.5 Leadership

(Source: 2020, Adapt from Partnership for 21st Century Skills)

Appendix 4: Learning Outcomes Questionnaire

Number…….

Learning Outcomes questionnaire

I am a student at Brunel University London, and I am surveying interest and learning from NSM Enjoy Makerspace activity. The following questions are designed to find out your opinions and interest in the NSM Enjoy Makerspace activity and learning outcomes of participation with the activity. Please complete this questionnaire, do not write your name because it is anonymous and confidential.

Part 1: <u>General Questions</u>

1. How old is participant? ☑ *The box*

☐ 10 - 12 ☐ 13 - 15 ☐ 16 - 19 ☐ 20 - 30

☐ 31 - 40 ☐ 41 - 59 ☐ 60 or over (___________years)

2. Is participant male or female? ☑ *The box*

☐ Male ☐ Female

3.What is participant's education? ☑ *The box*

☐ Primary school ☐ Secondary school ☐ High school

☐ Bachelor's degree ☐ Master's degree. ☐ PhD

☐ Professional Qualification

Part 2: <u>Your interest in NSM Enjoy Makerspace activity</u>

4. Do you usually make something for your daily life?

☐ Often ☐ Sometimes

☐ Seldom ☐ Never

5. What kind of thing that you like to make?

Your answer

……………………………………………………………………………………………………

……………………………………………………………………………………………………

6. What do you feel during you do it something by yourself (DIY)?

(Choose the only one character that the closest relate your character)

☐ Very easy ☐ Easy ☐ Hard ☐ Very hard

7. When you participate with NSM Enjoy Makerspace activity, what do you think about your learning from the task? *(Choose the option that most closely relates to your ideas).*

Topic	A lot	Some	Little	Nothing
1. Knowledge and understanding				
1.1 You learn how to finish task from the activity.				
1.2 You understand the process of making this task.				
1.3 NSM Enjoy Makerspace activity gives you specific information. For example, its history, how it is used by people or in places.				
1.4 NSM Enjoy Makerspace activity makes links and relationships between other things in life that you know about it. For example, people, animals, places, or objects.				
2. Skills				
Learning Skills				
2.1 You get intellectual skills from NSM Enjoy Makerspace activity. For example, ideas, thinking, making, listening.				
2.2 You get problem solving skills from NSM Enjoy Makerspace activity. For example, find the problem of making process, select variety ways for repairing or repair product of task completely.				

Topic	A lot	Some	Little	Nothing
2.3 You get communication skills from NSM Enjoy Makerspace activity. For example, listening to others, making yourself clear to others.				
2.4 You get s collaboration skills from NSM Enjoy Makerspace activity with your friends and family. For example, share the material with others, help other people to do task or collaborate with teamwork.				
2.5 You get creativity skill from NSM Enjoy Makerspace activity. For example, make a new product or find a new way for making process.				
Literacy Skills				
2.6 You get information literacy skills from NSM Enjoy Makerspace activity. For example, search more information from many media.				
2.7 You get Technology Literacy skills from NSM Enjoy Makerspace activity. For example, use computer and internet to complete task.				
Career and Life Skills				
2.8 You get flexibility and adaptability skills from NSM Enjoy Makerspace activity. For example, adapt suitable tools and material for making process and product.				
2.9 You get self-direction skills from NSM Enjoy Makerspace activity. For example, plan to finish product and project.				

Topic	A lot	Some	Little	Nothing
2.10 You get social skills from NSM Enjoy Makerspace activity with the toy with your friends and family. For example, meeting new people, sharing, team working, introducing others.				
2.11 You get productivity skills from NSM Enjoy Makerspace activity with the toy with your friends and family. For example, finish product of the project.				
3. Inspiration				
3.1 NSM Enjoy Makerspace activity makes you surprised.				
3.2 NSM Enjoy Makerspace activity inspire you to do the other task of making.				
3.3 NSM Enjoy Makerspace activity inspire you to develop more skills of maker in the future				
3.4 NSM Enjoy Makerspace activity inspire you to do the bigger project in the future				
3.5 You have positive attitudes with maker from NSM Enjoy Makerspace activity				
4. Creativity				
4.1 You have creativity after join NSM Enjoy Makerspace activity				
4.2 NSM Enjoy Makerspace activity prompted you to be creative				
4.3 After you have joined with NSM Enjoy Makerspace activity, you had innovative thoughts				

Part 3: <u>Environment and Recourses</u>

8. When you join with NSM Enjoy Makerspace activity, what do you think about the environment and resources in NSM Enjoy Makerspace area?

8.1 Environment

Environment	**Most conducive**	**conducive**	**Least conducive**	**Non-conducive**
1. The exhibition in the NSM Enjoy Makerspace area help your learning.				
2. The atmosphere of NSM Enjoy Makerspace area are suitable for your learning.				
3. The collection of the maker's tools and previous projects encourage your understanding more about the task, tools, and skills of this tools.				

8.2 Resources

Resources	**Most Appropriate**	**Appropriate**	**Least Appropriate**	**Inappropriate**
1. Explainer helps you to understand the process and skills of making the task				
2. Volunteer in your group foster you to understand and complete making the task.				

Resources	Most Appropriate	Appropriate	Least Appropriate	Inappropriate
3. The materials for making are appropriate and enough for your complete making the task.				
4. The handbook of NSM Enjoy Makerspace activity helps your learning and suitable for you.				
5. The task, which you make today is appropriate for you.				

Please add your comment about the NSM Enjoy Makerspace activity

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Thank you very much

Appendix 5: Engagement Observation Schedule

Number ……

Engagement Observation Schedule

The following questions are designed to find out participant's engagement with the NSM Enjoy Makerspace activity, when they participate with the task. As the observer, please observe the other participant and complete this observation schedule.

Part 1: <u>For observer</u>

1. Observer's name……………………………………………………………………………
2. Where is the observation?……………………………………………………………
3. Date……………………………Time……………………………………………………

Part 2: <u>About the participant</u>

Part 2.1: <u>General Questions</u>

1. How old is participant? ☑ *The box*

☐ 10 - 12 ☐ 13 - 15 ☐ 16 - 19 ☐ 20 - 30

☐ 31 - 40 ☐ 41 - 59 ☐ 60 or over (____________years)

2. Is participant male or female? ☑ *The box*

☐ Male ☐ Female

3.What is participant's education? ☑ *The box*

☐ Primary school ☐ Secondary school ☐ High school

☐ Bachelor's degree ☐ Master's degree. ☐ PhD

☐ Professional Qualification

Part 2.2: Observation seeks to find out the participant's engagement with the NSM Enjoy Makerspace activity**, what the participant joins the activity. Please record your observation two times. First, observe for the first minute, when the participant sits and listens to the explainer and, second, observe the participant what he/she starts following the activity and does task** *For each* **(***type of engagements, choose the scale that relates closest to your observations and check only one box for the First minute and only one box for the When participant starts the activity and take not below*.**)**

4 Most engaged 3 Quite engaged 2 Not quite engaged 1 Not engaged

Type of engagement	Sub-category	First minute				Participate with. the task			
		1	2	3	4	1	2	3	4
1. Engagement with the activity	• Observes the activity strongly and involved • Observes the activity strongly and involved • Succeeds in the goals of the activity								
		Note				Note			
2. Learning from the activity	• Follows the activity • Asks Questions • Answers the questions • Practice skills	1	2	3	4	1	2	3	4
		Note				Note			

Type of engagement	Sub-category	First minute				Participate with. the task			
		1	1	2	3	4	2	3	4
3. Involvement in their group	• Shares the materials or tools with others • Help others to do task • Practice the task with others • Talks or discusses with others	Note				Note			
4. Engagement with environment and resources	• Explores environment and resources • Learn the material and learn how to use equipment. • Cooperate with the Explainer and Assistants Interested in the Maker Space handbook								
		Note				Note			
5. Expression and conversation	Verbal/explain, asks questions, answer questions, expresses like/dislike, conversation, etc.) Present in the conversation form.								
		Note				Note			

Adapted from Kanhadilok **(**2013**).**

Summarise participant scores

1. The total scores in the first observation is .... **points**

   The character of the participant in the first observation is ....

....

....

....

....

....

2. The total scores in the second observation is .... **points**

   The character of the participant in the second observation is ....

....

....

....

....

....

....

The meaning of the total scores

Most engagement	Quite engagement	Not much engagement	No engagement
10 - 12	7 - 9	4 - 6	1 - 3

Appendix 6: Motivation and Learning Outcomes Interview

Number…….

Motivation and learning outcomes interview

Introduction: My name is Sucharit Ponrueng. I am a student at Brunel University London, and I am interested in motivation and learning outcomes of participating when participates with NSM Enjoy Makerspace activity. This interview will be anonymous and confidential you do not need to answer your name.

Part 1*:* <u>General background</u>

1. How old are you? ……………………… years
2. **(**Observes gender**)** ☐ Male ☐ Female
3. What is your education?
   - ☐ Primary school ☐ Secondary school ☐ High school
   - ☐ Bachelor's degree ☐ Master's degree. ☐ PhD

Part 2*:* <u>Motivation from NSM Enjoy Makerspace activity</u>

1. What do you interest to join the NSM Enjoy Makerspace activity?

Give your reason.

Answer …………………………………………………………………………………………

……

……

2. Do you achieve to finish the task of the activity? and how do you feel?

Give your reason.

Answer …………………………………………………………………………………………

……

……

3. Do you have self-efficacy from NSM Enjoy Makerspace activity? and how? *Give your reason.*

Answer ....

....

....

Part 3: **Learning outcomes from NSM Enjoy Makerspace activity**

1. Does NSM Enjoy Makerspace activity help you understand more about the content of the task? and how? *Give your reason.*

Answer ....

....

....

2. Does NSM Enjoy Makerspace activity help you to develop more skills? *Give example and reason.*

Answer ....

....

....

3. Does NSM Enjoy Makerspace activity inspire you to learn more about maker's knowledge, skills, and innovation? And how**?** *Give your reason.*

Answer ....

....

....

4. Does NSM Enjoy Makerspace activity help you to develop creativity? How? *Give your reason.*

Answer ....

....

....

Thank you very much

Appendix 7*:* Ethics Form

College of Business, Arts and Social Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

29 June 2022

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 30/06/2022 AND 30/06/2023

Applicant (s): Miss Sucharit Ponrueng

Project Title: An investigation of the experiences and learning outcomes of family visitors to the NSM Enjoy Makerspace, at the National Science Museum (NSM), Thailand.

Reference: 30671-MHR-Jun/2022- 39681-2

Dear Miss Sucharit Ponrueng

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor David Gallear

Chair of the College of Business, Arts and Social Sciences Research Ethics Committee

Brunel University London