Application of Creative Thinking Skills (CTS)

in STEAM-based Activities in a Hong Kong School:

Instrument adopted, Attitudes changed and Principles derived

by

LO, Kit Mei Jammie

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Statement of Originality

I, LO, Kit Mei Jammie, hereby declare that I am the sole author of the thesis and the material presented in this thesis is my original work except those indicated in the acknowledgement. I further declare that I have followed the University's policies and regulations on Academic Honesty, Copyright and Plagiarism in writing the thesis and no material in this thesis has been submitted for a degree in this or other universities.

Abstract

The purpose of this study is to examine students' creative thinking skills in STEAM-based activities by using the *Makey Makey* invention kit in designing the human-centred design instruments (HCDIs). Human-centred design is a process of designing for people (IDEO, 2011). This research aims to investigate the application of students' creative thinking skills in developing solution to problem in human perspectives in everyday life through designing the human-centred designed instruments with the combination of creative exchange of knowledge and personal experiences between the designers (students) and users in different age group.

Data were collected from 264 adolescent females (n = 264) in the age between 11 and 13, who had participated in the STEAM-based activities in a Hong Kong local secondary school. The STEAM project was provided through the school curriculum to examine the students' level of creative thinking across disciplines in designing the human-centred design instruments (HCDIs) with *Makey Makey* to match the actual needs of different age groups, including children (aged 3-6), adults and elderly (aged over 65). The research objectives are concerned with the students' involvement and attitude in participating the STEAM-based activities as well as their application of their creative thinking skills in the real-world context. The students' experiences of thinking creatively were investigated through the five stages of creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007) in STEAM-based activities in Hong Kong context.

Pre- and post-treatment attitudinal questionnaires, two class observations and four interviews with both teachers and students were conducted to examine the change of students' attitude towards creative thinking. Data findings revealed that 1) a slight increase in the students' level of attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) with the invention kit *Makey Makey* after participating the STEAM project was shown in the dimensions of originality, flexibility, fluency and elaboration based on the modification of the creativity measurement framework from the Runco Ideational Behavior Scale (RIBS). 2) creative thinking was promoted through experiencing the real world and tackling the actual problem in the stage of imagine, create, play, share and reflect which were suggested from the framework of *Creative Learning Spiral* by Mitch Resnick (2007).

Based on the literature and results shown in this paper, a STEAM-specific Creative Learning-thinking Model (CLTM) in 10 guiding principles for the curricular design in STEAM-based activities was built and further explained the complexity happened within each stage in the application of the STEAM context, based on the framework of *Creative Learning Spiral* by Mitch Resnick (2007), with the consideration of the availability of tool and the students' attitude throughout the STEAM project in Hong Kong context. A set of assessment rubrics was designed for in-service teachers in implementing the STEAM-based activities in classroom settings.

Keywords: Creative Thinking, STEAM Education, Human-centred design instruments, *MakeyMakey*, Creative Learning Model

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List of Abbreviation

HCDI Human-centred design instrument

STEAM Science, Technology, Engineering, Arts and Mathematics

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I. INTRODUCTION

1.1 Background of the Research

Science, Technology, Engineering and Mathematics (STEM) education has increasingly been applied in curricula in recent years but is regarded as bounded within particular disciplines. In the 21st century learning, it is very crucial to inspire students to be creative and innovative for getting ready to solve the the real-world challenges and problems (Rahmawati, 2019). As arts-infused education is highly recognized in developing creativity (Park & Ko, 2012), integrating art-related skills in teaching and learning activities of STEM education may support the learning domain in STEM, switching the learners from computational thinking to creative thinking. Partnership for 21st Century Skills (2008) stated that students should be well-equipped with learning & innovation skills to get ready for solving the problems. These learning & innovation skills include critical thinking, problem solving, creativity & innovation, communication & collaboration. The integration of arts (A) into STEM, which means adding "A" into the foundation of STEM, helps to encourage learners' creativity and students are taught to think comprehensively across disciplines (Sheffield, et al.,2018; Yakman & Hyongyong, 2012).

Arts-infused education is essential in leading students to develop new directions and can help determine how and to what extent educators can instill a new kind of transdisciplinary learning, which facilitates creative thinking within the relevant community. "Arts-infused" education and "Arts-integrated" education is sometimes used interchangeably (Parsons, 1998). STEAM-based activities integrated into school curriculum in classroom setting enables students to learn, analyze and solve the problems across disciplines with the use of technology tools (Blumenfeld, et al., 2011). It is predicted that the problems in the world would be increasingly complex and new solutions are necessary. The learning mode is essential to be switched from professional learning to lifelong learning for sustainable future. Arts-infused education can provide student with experiences to connect knowledge creatively with meaning in the real-world context, shifting from computational thinking to human-centred learning.

The purpose of this study aims to investigate the application of students' creative thinking skills in developing solution to problem in human perspectives in everyday life through designing the human-centred design instruments (HCDIs) for human needs in different age group by using the *Makey Makey* invention kit. *Makey Makey* is a simple device that is popularly used in the education setting with notable results (Abrahams, 2018). It consists of a circuit board with a microcontroller, connecting the computer without installation of drivers or software and allows sending keyboard or mouse events to the connected computer (MIT Media Lab 2015).

This current study marks a critical step in this direction by drawing attention on how to stimulate students' creative thinking based on the implementation of the STEAM project and explore possible research directions. It can enable the construction of a curriculum design pedagogical framework for teacher training in arts-infused education, along with the conceptualization of a learning-thinking model in future STEAM education. It is a self-funded pilot study with empirical data in academic base, which provides information and data to inform policy with government bodies, non-government organizations, entrepreneurs, and STEAM experts.

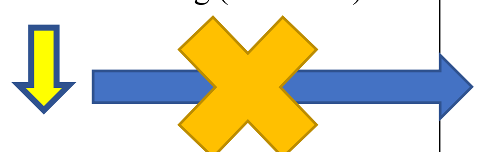
Framework of the Study			
"Creative Learning Spiral" (Spiral) by Mitch Resnick (2007)	**Application of Creative Thinking Skills into STEAM-based activities in Hong Kong context**		
Research Logics	**1. Makey Makey as a platform for human-centred design instrument?**	**2. Hong Kong students' involvement and attitude in STEAM-based activities?**	**3. Same Spiral works in STEAM-based activities in Hong Kong?**
Research Questions	**<u>Research Question 1</u>** How can the human-centred design instruments (HCDIs) be applied as a tool in STEAM-based activities in Hong Kong context?	**<u>Research Question 2</u>** How do students' attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) in STEAM-based activities in Hong Kong context?	**<u>Research Question 3</u>** How do students experience the five stages of creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007) in STEAM-based activities in Hong Kong context?
	• The application of HCDI (Makey Makey) in the STEAM project  *Instrument adopted*	• students' attitude change towards creative thinking (increase?)  OR • students' attitude change towards creative thinking (decrease?)  *Attitudes changed*	• How to conceptualize the "Creative Learning Spiral" by Mitch Resnick (2007) in STEAM Education? I : Imagine ↓ C: Create ↓ P: Play ↓ S: Share ↓ R: Reflect *Principles derived*

Table 1.1: Framework of the Study

1.2 Framework of the Study

Table 1.1 shows the framework of the study with the three research questions. There are three theoretic issues to be addressed in this study. The first issue is to explore how the *Makey Makey* invention kit can be applied as a tool for students to design a human-centred design instrument in STEAM-based activities. The second issue is to investigate how students' attitude changes towards creative thinking through hands-on experience in designing the human-centred design instruments (HCDIs) in STEAM-based activities. The third theoretic issue is about how to help students experience the creative thinking in STEAM-based activities. It is beneficial for both educators and students if there are guided principles and concrete framework about the curriculum design for STEAM projects in school setting. As such, it is worthy to investigate how the students in experiencing the creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007) through the STEAM project.

1.3 Statement of the Problem

It was perceived that many previous studies were shown on how to help teachers learn technology, but knowledge of technology does not necessarily lead to effective teaching with technology (Koehler & Mishra, 2008). It is important for educators to consider how to guide students to go beyond the disciplinary content for higher level of creative thinking and organize music-related activities across the different key learning areas in the curriculum in order to equip students with the capability in examining the issue from various points of view, rather than only focusing on the quality of the music product.

From the STEAM project in this research, it provided students to experience creative thinking and transform new knowledge across disciplines when creating human-centred musical instruments for different human needs. It is suggested that student engagement in creative process should be highlighted in arts-infused education for developing connections with other subjects and disciplines in a meaningful way (Silverstein & Layne, 2010). Students experienced the elements of “Arts” and connected the knowledge from other disciplines including science, technology, and mathematics in designing the human-centred design instruments. It aligns with the rationale of the STEAM education. In STEAM education, students are expected to construct meaning in various subject areas through integrated art infused education with the connection of knowledge, experience, sense and feeling in transdisciplinary learning (Henrkisen, D., DeSchryver, M., & Mishra, P., 2015).Through the engagement in this creative process, it is seen that the premise of arts-infused teaching and learning highlights the diverse understanding of a concept in life application.

Around the globe, STEAM education is getting popular in recent years and prior studies show that most educators support this integrated strategy to large extent (Han & Lee, 2012) and recognize its positive impact on students’ thinking and learning beyond disciplines through practical solutions that are interrelated to our everyday life (Mishra, et al., 2013). In the Arts Education Key Learning Area Curriculum Guide by the Hong Kong Education Bureau (Education Bureau, 2017), it was stated that the objectives of promoting STEM education are to strengthen students’ integrated knowledge and skills across disciplines, nurture their creativity and problem-solving skills for innovative ideas in this evolving society. The elements of arts (A) are encouraged and it is highly recommended for students to apply technology in different means of creative arts. However, there is no concrete guidelines on STEAM education from the Hong Kong Education Bureau. No curriculum guide or official documents about STEAM education were published by the Hong Kong Education Bureau and therefore under the lack of coherent education policy, it leads to the insufficient teacher’s expertise to implement the lessons in general trend. Geng, Jong & Chai (2018) conducted a research about Hong Kong Teachers’ self-efficacy and concerns about STEM education. It was mentioned that over half of the teachers in Hong Kong are not ready for the STEM education and most of them had concerns about the teaching resources, class and instructional implementation and teacher training. It is observed that there is an enormous gap in promoting STEAM education between the education policy and the actual situation. As such, it draws the attention from the researcher to further investigate the application of students' creative thinking skills in developing solution to problem in human perspectives in everyday life through the STEAM-based activities of designing the human-centred musical instruments for different age groups in society, with the combination of creative exchange of knowledge and personal experiences between the designers (students) and users in different age groups.

1.4 Significance of the Study

In this increasingly complex and technologically driven world, education should not be only focused on the understanding of knowledge, but to build up the capacity of socio-technical contribution to the society. The direction of arts education is increasingly focused on developing creativity, understanding cultural contexts and cultivating critical thinking and response (EDB, 2017), which have not been highlighted much in traditional classrooms. While shifting to less emphasize on the skill mastery, many prior studies show that technology supports creativity through improvisation (Mellor, 2008; Partti & Karlsen, 2010) and concepts are identified and learnt in more than one discipline. In this rapidly changing digital age, the use of technology and interactive media can provide engaging arts experience and motivations to learners that optimize the potential for learning for life.

In the Arts Education Key Learning Area Curriculum Guide by the Hong Kong Education Bureau (2017), technology is highly recommended to be applied to explore different means of creating and performing arts in the development of arts education in Hong Kong (Education Bureau, 2017). Technology acts as a crucial stimulator and possibility to provide a platform for students to learn with their own input of ideas in a more progressive manner. In this research, students can actively engage in sound exploration, improvisation and experimentation - combining different sounds and rhythms to create unique music in an amateur level that can demonstrate an individualistic form of communication and artistic expression, with the application of the invention kit *Makey Makey,* which serves an interface connecting the computer to create human-centred designed instruments (HCDIs) for different human needs of various age groups in the society. Active music making helps children to stimulate creativity, and it is also recommended that the process of creative thinking is much more highlighted (Webster, 1990). This kind of experiential learning raises the intellectual and social development through actively engagement in music (Hallam, 2010), instead of focusing on the technical skills in music performance. This STEAM-based activity brings music to the level that not only for the purpose of performance or appreciation, but to encourage students to think and learn across the arts and science, from knowledge consumption to social contribution in order to raise the quality of life.

It then leads to the significance of the study to draw attention on constructing the creative learning-thinking model and providing some guiding principles for educators in the curricular design and conceptualize the teaching and learning practices in STEAM-based activities in Hong Kong in the future.

As such, the current study is guided by the following research questions:

1. How can the human-centred design instruments (HCDIs) be applied as a tool in STEAM-based activities in Hong Kong context?
2. How do students' attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) in STEAM-based activities in Hong Kong context?

3. How do students experience the five stages of creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007) in in STEAM-based activities in Hong Kong context?

II. LITERATURE REVIEW

The literature review identified and synthesized the relevant empirical research in the area of creative thinking in STEAM-based activities. This chapter starts by defining and discussing the creative thinking in arts-infused education and specifically focus on the creative process as a "Creative Learning Spiral" by Mitch Resnick (2007). Furthermore, the application of the *Makey Makey* invention kit and the concepts of human-centred design instruments (HCDIs) will be highlighted in this chapter. Both teachers and students' attitude towards creative thinking and the implementation of STEAM-based activities will also be examined in order to address the research questions in this study.

2.1 Creativity and Creative Thinking

The concept of creativity has a wide spectrum of definitions and is always controversial (Ochse,1990; Craft, 2001). It brings different meanings and interpretation in the views from different scholars across generations in the thinking and learning process.

The concept of Creative thinking was firstly presented by Graham Wallas (1926) and he considered creative thinking as an individual thought process in four stages, which are preparation, incubation, illumination and verification. He mentioned that creative thinking did not happen in a linear way. The whole process could be messy, but new insights and connections might take place in this messiness (Wallas, 1926).

Many scholars introduced different models of creative thinking process, based on the foundation of stage theory by Graham Wallas. The view towards creative thinking by J. P. Guilford (1950) is more in-depth than Wallas (1926). Other than focusing more on the process of creative thinking, Guildford (1950) brought more attention to human development. He believed that both convergent and divergent thinking abilities are essential to develop insights in human problem solving and it was correlated with one individual's behavioral pattern through the identification of personality characteristics.

Guilford (1950) was one of the earliest scholars who pursued the empirical studies of creative thinking. He considered that creativity was a process of thinking, which was the person's potential in creativity. From Guildford's (1967) book, *Nature of Human Intelligence* , it mentioned that creativity involved divergent thinking with possibilities that aimed to explore or find multiple answers for problem solving in new territories or to revise the existing thinking. In his view, creative thinking process includes the elements of sensitivity, fluency, flexibility, originality and elaboration. Clark and Mirels (1970) explicitly stated that fluency was highly interrelated with creativity and it is a pervasive element in the measurement of creativity. Students in high level of fluency may produce numerous ideas and provide multiple possibilities or solutions in problem solving. Views towards creativity from Fasco (2001) aligns with Guilford's principles and he stresses on more about the level of participation in the process of creative thinking. Hands-on experience may directly generate new ideas and enhance the skills in fluency, flexibility, originality and elaboration (Fasco, 2001). Vygotsky (2004) considered any human act which generated something new as creative act and imagination is the ability of human's brain to combine elements based on this creative act. It is shown that imagination plays a very important role in promoting creativity and it is one of the components of creativity. Higgins (2008) holds the same view that creativity has a very close relationship to the development of imagination.

Kratus (1990) described each of the creative act should consist of three components (3Ps), which are the person who is creating, the creative process and the creative product. More scholars put forward the discussion and agreed that creativity includes four component (4Ps), which are creative person, creative process, creative place and creative product (Donelly, 2004; Fryer, 1996;

Hickey & Webster, 2001; Stavrou, 2013; Sternberg, 1988). It is powerful to approach the problem by going through these four facets in order to recognize the solutions during the incubation period. These 4Ps are interrelated: The creative ability of an individual varies, depending on the willingness to think divergently and convergently. The way he or she thinks in the creative problem-solving process is also affected by the environment in which creativity may happen, leading to different kinds of creative product (Vogel, 2014; Brunn, 2019).

There are different creativity models to explain the process of creativity and identify the components of producing creativity. Torrance (1979) initiated a creativity test about creative thinking based on fluency, flexibility, originality and elaboration. Hickey (1995) generally states that creativity is any process or product, which is the result of creative thinking. Diehl and Stroebe (1987) stated that ideas generated from a creative activity are the output of creativity and they could be measured in quantitative and qualitative way. It is easy to measure the number of ideas (fluency), but it is more complex to measure the uniqueness of the ideas (originality). Webster (2002) constructed a conceptual creative thinking model in music. It outlines the creative process. It is considered as a mental process of convergent and divergent thinking with intention and ended with a creative product. Haroutounian (2002) deliberated characteristics of creative thinking in a more in-depth way as fluency, flexibility, originality and ability. Fluency refers to numbers of ideas and solutions. Flexibility is the ability in investigating a topic from different perspectives. Originality refers to the uniqueness of idea that an individual can create, while the ability refers to the skills in elaboration or extend the ideas further. Wright (2010) stated that there were seven steps in creative including findings and problem solving, flexibility, fluency, elaboration, transformation, objectivity and selectivity, and aesthetic appreciation. It is obviously seen that many scholars view that creativity is not determined by any single attribute and it is suggested that the assemblage of intellectual abilities, domain knowledge, flexibility in thinking, personality, motivation and supportive environment may contribute to raise the level of creativity (Sternberg and Lubart, 1999).

In recent years, the concept of creative thinking is more advanced and focused much more about the considerable value in the society. Creativity allows an individual in developing new ideas and be flexible with the capacity to deal with the challenges in daily life and contributes to raise the standard of living and economic productivity (Runco, 1986; Runco, 2007). Mark and Garrett (2012) pointed that creativity required two elements, which were originality and effectiveness in an article “The Standard Definition of Creativity”. A creative idea is expected to be unique and unusual – an invention with value. It aligns the view with Gaut & Livingston (2003) that creativity is a way of “making something” (Gaut & Livingston, 2003) and this product requires to be original and notably new. They both mentioned that originality and value plays an important role in determining the learning process is creative or not. For this creative act, it is a process of producing something with value, but it is not indispensable that there must be a creative outcome generated during the creative process. To judge the creative thinking in the learning process, it is needed to eliminate the case of making by chance or following mechanical procedure.

National Advisory Committee on Creative Education (NACCCE) (1999) defines creativity as an imaginative activity that fashions children’s outcome and the products are original and of value (Haroutounian, 2002). Creativity is a kind of ability to associate knowledge in disparate disciplinary contexts in a unique way which includes practical use and value adding (Higgins & Morgan, 2000; Jackson & Shaw, 2006). Sæbø, McCammon and O’Farrell have similar views on creativity that it involves different senses of mind including seeing, thinking and innovating, which is the mental process that are not processed independently (Sæbø, McCammon and O’Farrell, 2006). Creativity is an active process, which requires knowledge and skills for innovation. Problem setting and solving is involved in the process of learning to foster creativity (Stavrou, 2012).

2.2 Creative Thinking in Education

Creativity is an undeniable element in education and it has been valued from the educational reform movement in the United States since 1950s (American Association for School Administrators, 1959). It is indisputable that children should start learning from early stage for sustainable development. Learning turns meaningful when it takes place from theoretic knowledge to the context of practice. Knowledge was enriched, based on experience from situation and social values (Rankin & Brown, 2016).

Creative thinking is a complex issue and it may take place in different fields including education and psychology, which both create impact to students' learning. In general, creative thinking can be defined as the "interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as designed within a social context" (Plucker, Beghetto & Dow, 2004, p. 90). Creative thinking allows students to engage in divergent thinking in subjective manner, leading to ideas of invention for problem solving in the society. It aligns the view from Soo (2002) that creativity in problem-solving is the main driver of creating new knowledge innovation. Creativity is considered to the key to innovation (Amabile, 1998, p.126) and it is shown that creativity is one of the crucial factors that enhance civilization in the society (Hennessey & Amabile, 2010). Creativity builds a strong relationship with imagination as it aims to break through the existing ideas for creating new and cutting-edge ideas. Creativity plays an important role to generate an answer to overcome the problem. This kind of creative thinking enables learners to come up with innovative solutions to the problems that may happen in our everyday life (Sawyer, 2006). It is very essential to provide opportunities for students to be creative thinkers and engage in the creative process, including the idea generation, experiments, collaboration and sharing over time (Resnick, 2019).

The concept of creative thinking raise attention over the years as all levels of stakeholders such as educators, parents, employer and policy-makers understand that being creative is crucial to address the problems in the future. MacKinnon (1975) has delineated the criteria of being a true creative person should be involved a sustaining original insight, evaluation and elaboration. He pointed out the importance of elaboration was the ability to add details on a general idea with quality in order to build up an original idea. Cropley (1992) claimed that teachers who supported to promote creative thinking should offer opportunities for students to explore and play with problems and materials in order to foster the divergent thinking skills. Bateson (1999) stated everyday creativity is an essential component in education, because innovation motivates an individual to learn and grow throughout life. Csikszentmihalyi (1996) mentioned that creative thinking happens in the interaction between a person's thoughts and a socio-cultural context. Children's culture is viewed as distinctive and acts as an active role to develop the creative products, rather than being a follower in adapting the adult-generated culture (James et al., 1998; Corsaro,2000). Torrance (1998) stated that creative thinking was considered as a process to sense a problem and difficulty, and thereafter finding information for a solution. Students can perform the role as designers of knowledge with creativity and collaborate with influences in the social environment interactively (Boy, 2013). Sternberg (2006) mentioned that children were able to perform better in problem solving if they were allowed to think creativity, instead of learning and understanding the model answer.

Creative thinking and critical thinking are closely correlated. Weston and Stoyles (2007) stated that creative thinking complements critical thinking while Pavill (2011) stated that creative approaches foster critical thinking. Creative approaches may encourage students to take ownership of the problem. Sternberg and Lubart (1995) consider that creative thinking is an innate talent but needs to be nurtured. It can strengthen the divergent thinking process and allow new and different skills in problem solving.

2.3 Arts-infused Education

Arts-infused education is a kind of multi-disciplinary practice, which is opposed to a mastery learning in specific discipline. It is suggested that student engagement in creative process should be highlighted in arts-infused education for developing connections with other subjects and disciplines in a meaningful way (Silverstein & Layne, 2010).

From the curriculum guide prepared by The Curriculum Development Council (Hong Kong) in 2017, arts education includes the expressive arts subjects such as music, visual arts, dance, drama, media arts and other arts form (Education Bureau, 2017). It is recommended to balance the curriculum by incorporating the creative thinking for further developing the ability of self-expression through the understanding of the conceptual knowledge during the learning process. Many scholars also believe that arts interact with disciplines including mathematics and language, which encourage the creative and critical thinking (Isabell & Raines, 2007; Marshall, 2005; Nilson, et al., 2013).

"Arts-infused" education and "Arts-integrated" education is sometimes used interchangeably (Parsons, 1998). It is shown that various terms are applied and defined in the literature. Bresler (1995) mentioned that arts-infused education is one of the synonyms representing the context in arts-integrated education. The root of arts-infused education was from the progressive education, which was highly promoted in the early 20th century. Dewey (1934) placed emphasis on aesthetic experience and encourage educators to learn through the interrelations among subjects for holistic development (Bresler, 2003). Mason (1996) holds similar view and believes arts integration benefits to the child development in connected ways of knowing, leading to a higher level of holistic thinking. Brown (2007) claims that art-infused education may help to challenge students to do something of value in order to have a deeper and meaningful understanding of the information and concepts. As such, arts-infused education is considered as an internationally recognized phenomenon and it is popular to integrate arts into traditional curriculum in an interdisciplinary manner nowadays (Barrett, 2001; Burton, 2001; Chrysostomou, 2004).

Arts-infused education is getting very popular around the globe, including USA, Europe, Australia, Canada and Singapore (Cheng, Chou and Cheng, 2014). Arts education successfully infused in the entire education system and holds the same value as other subjects in in Finland (Nevanen, 2015). The education in Europe encourages play and creativity. Cohen (2016) stated that Americans for the Arts conducted a national survey about the opinion on the arts and arts education in 2015. Over 88% of the American public arts should be considered as part of a well-rounded education for K-12 students while over 83% of respondents agreed that it was important to receive arts education and nurture the creativity across all levels of K-12 education (Cohen, 2016). This education trend is in expectation based on the benefits of children development as well as the increasing support in teacher training.

2.3.1 Importance of Arts-infused Education to children's creativity development

The report published by National Advisory Council on Creative and Cultural Education (NACCCE, 1999) from United Kingdom mentioned that one of the main criteria for the current and future needs in the field of human resources is innovative and creative staff. The ability to think creatively and innovatively is very essential to develop the 21st century learning and life skills such as critical thinking, effective communication and collaboration in order to raise the competitiveness in the community (Trilling & Fadel, 2009).

Many scholars agree that the active engagement in quality arts education is able to positively affect students' overall academic achievement and the development of empathy (Fiske, 1999; Deasy, 2002; Board of Studies NSM, 2006; Ewing, 2010). Cornett and Smithrim (2000) support to integrate arts into regular curriculum in early childhood education as they think that feeling or expression cannot be reduced to words only. They believe that there is a positive relationship between arts and academic success as students may develop a sense of perseverance through learning and appreciating arts. Eisner (1998) states that arts has the power of subtleties while spoken and written language cannot describe all human's feeling and cognition. The book "Arts with the Brain in Mind" authored by Jensen (2001) stated examples of cognitive research, which was supportive to implement arts programs at schools. From the observation of his own research about brain, arts and learning, he claims that arts education is essential for children development. It aligns the view from Eisner (1997), who mentions each of the art forms is a special way of perceiving and thinking in many forms of representation to understand the culture fully and build up the full capacity of mind (Eisner, 1997). Bredekamp & Copple (1997) clearly state those expressive arts subjects are the explicit focus in children's learning and inspire children for self-expression in variety of forms as follow:

"*Art, music, drama, dance, and other fine arts are the explicit focus of children's study at times. On other occasions when relevant, the fine arts are integrated in other areas of the curriculum, such as social studies or mathematics. Children are encouraged to express themselves physically and aesthetically, represent ideas and feelings, and acquire fundamental concepts and skills in the fine arts." (p. 174)* (Bredekamp & Copple, 1997)

Soden, Seagraves and Coutts (2008) from Scotland agreed that infusing art into traditional academic subjects like Mathematics with Visual Arts, English with Performing Arts, was able to inspire the students and raise their engagement and learning motivation in learning. Chicago Arts Partnership in Education (CAPE) promoted arts-driven education to cultivate students' critical thinking and stimulate creativity. The main highlight of this arts-infused education is the collaborative curriculum design by artists and teachers, which allows artists to have a more in-depth understanding of curriculum subjects (Coutts *et al*, 2009). It helps to strike a good balance between arts and traditional academic subjects and soothe the pressure from the generalist teachers. Moreover, arts-infused education acts as a strategy for students to pave the way to higher level of creativity through participating and experiencing in different forms of creative arts joyfully (Cheng, Chou and Cheng, 2014). As such, it is obviously seen that the implementation of arts-infused education is able to foster students' creativity and benefits their learning.

2.3.2 Teacher training in Arts Education around the globe

Governments from different nations have increased emphasis in the implementation of arts education. To align with the global education trend, the Republic of China (Taiwan) enacted the "Art Education Act" in 1997. The White Paper of Art Education Policy in 2005 also clearly showed the direct support from Taiwan government. Based on the Art Education Law, arts education training started to take place at professional arts institutions or regular schools. It successfully raised the quality and level of teaching approaches in arts and related teaching materials. Four-year arts education programme was launched in 2005 and its objective was to integrate arts with other academic subjects (Ministry of Education, 2005).

In United States, teacher training programs of arts education have been influenced by the values of different American education institutions due to the complex relationship to social structure and culture (Hueneburg, 2016), but not directly related to government policy. In recent years, arts education graduates must have the appropriate expertise and experience for teaching arts from grade K-12. It speaks the progressional development of arts education and keep up with current issues in the entire education system and builds the ability of the educator to infuse arts elements in classroom teaching.

In Australia, it was noticed that arts education teacher training started in 1980s but unfortunately the majority of the educators were not well equipped with the preservice training in teaching arts (Task Force on Education and the Arts, *Action: Education and the Arts*, Report to Minister for Education and Youth Affairs, Canberra 1985). In the millennium, there is still an enormous gap between the expectations of arts-infused curriculum frameworks and initial teacher education in arts education (Alter et al. 2009). Arts education was scheduled to implement in the new National Curriculum in 2014. However, its position is variable. Only music and visual arts were legislated included in the curriculum while dance and drama were taken as extra-curricular activities (Nilson, Fetherston, McMurray & Fetherston, 2013).

It is seen that teacher education providers, curriculum developers and policy advisors substantially contribute in supporting and enhancing positive perceptions of arts education. It is still one of the highlights in the education system.

2.4 Attitudes towards creative thinking in arts-infused education

2.4.1 From Educators' Perspective

i) Knowledge

It is a controversial issue that most of the in-service generalist teachers are lacking professional arts knowledge and requisite experiences to teach effectively in arts-infused education.

Many scholars (Eisner, 1994; Welch, 1995; La Pierre & Zimmerman, 1997) doubted whether the generalist teachers with no substantial specialized arts knowledge are capable to implement arts-infused education and stimulate students' creative thinking. Russell-Bowie (2006) have different views and they believe classroom teachers may have better knowledge and relationships with students. Generalist teachers in classroom may have a thorough understanding of the everyday curriculum and they are in better position to integrate the level of arts into the regular curriculum. However, it is also shown that the inadequacy of arts education in teacher education brings negative impact to the readiness for generalist teachers and even brings anxiety. Garvis and Pendergast (2010) found that all 201 beginning teachers from Australia as participants in their study did not have the perceived capability to teach all of the arts. It is known that most arts education teaching training for primary schools offered by universities only lasts for one semester ranging rom six to thirteen weeks (Lemon & Garvis, 2013). Many teachers reflected that the training was inadequate to support their future teaching. Wright (1999) conducted an exploratory study investigating the drama anxiety experienced by the generalist teachers. Most of these educators felt nervous and anxious, but with no physical symptoms. It is found that the most efficient way to minimize this anxiety would be strengthening the development of the foundation knowledge and skills. Russell-Bowie (1993) and Saebo (2009) showed that the educators' personal experience in arts education and their creative abilities affect their teaching effectiveness as well as their attitude in the art-infused education.

ii) Confidence

Welch (1995) figured out that one of the obstacles that the educators faced was lack of confidence due to their abilities and skills in assisting the students' learning in arts education. Russell-Bowie and Dowson (2005) conducted a study about the relationship between the level of arts background and confidence across five countries including Australia, Namibia, South Africa, United States and Ireland. It is reflected that most of the generalist teachers had very few formal background and training in any forms of arts. As the result, the level of confidence diminishes as the generalist teachers do not think that they have significant skills and knowledge to facilitate student learning in creative arts.

iii) School support and value

Holt (1997) from United Kingdom believes that values and attitudes are very crucial to the purpose of the creative arts in education. Eisner (1997) from United States holds similar view and it is shown that many generalist teachers are not familiar with the teaching content including arts elements. They don't receive any concrete support from schools and teaching materials are not easily accessible. As such, it leads to low levels of esteem due to lack of initial training and support. Pateman (1991) stated that some generalist teachers were insecure when implementation the arts-infused education and inevitably considered arts education as peripheral. It is always difficult to judge an arts-infused curriculum as "good" or "bad" (Wheat, 2005)

It is noticed that many educators avoid creative behaviors from students as some teachers misinterpret them as disruptive behaviors and affect the class disciplines (Westby & Dawson, 1995; Runco, 2002; Alughaiman & Mowrer-Reynolds, 2005). Other than that, many educators feel pressured that there are no standardized evaluation systems to identify or quantify students' strengths and weakness. Both teachers and parents feel not comfortable when they cannot assess students' achievement in an exam-based system and it lowers the level of enthusiasm to engage in continual teaching and learning in arts-infused education.

2.4.2 From the Students' Perspective

There is substantial evidence showing that supporting learning through arts increases students' motivation. A study conducted by Cheng (2010) shows that students were more active in creative learning. They had a high sense of self-satisfaction in the activities, but they did not focus too much on the creative elements. Most students valued the gain of wider range of knowledge with meanings from different disciplines and were able to apply it in daily life. Pavlou and Kambouri (2007) agree that the factors leading to positive attitudes from students towards arts- infused education are the level of interests, difficulty and success (West, Hailes & Sammons, 1997). Todman and Dicky (1993) showed an interesting observation that students' attitude change related to teachers' attitude towards arts education. Students may doubt the usefulness towards arts education when they found that their teachers treated arts as a peripheral subject (Dyson, 1989). As arts education allows many connections among various fields, students' experience in cross-subject integration brings interest to their learning and raise their motivation. Students are more willing to express and able to demonstrate better interpersonal relationships (Denac, Cagran, Denac & Kafol, 2013). Moreover, learning environment is one of the factors affecting the level of children's creative thinking and their creative impulse were repressed in restrictive thinking environment (Nilson, et al., 2003). It is seen that children's autonomy and creativity were dependent for their distinctive ideas or solution (Schirrmacher & Englebright Fox, 2009). All in all, students feel supportive to arts-infused education and they feel enjoyed in learning and be more confident in personality.

2.5 Creative thinking in arts-infused education

Expressive arts subjects in arts education such as music, visual arts, dance and drama were recommended to balance the curriculum by incorporating the creative thinking for further developing the ability of self-expression, imagination and problem solving through the understanding of the conceptual knowledge during the learning process (Power & Klopper, 2011). Runco (2014) stated that art is classified in a definite creative domain. Creative breakthrough is essential to broaden the context and establish links to construct new knowledge. Swanwick (1992) determined that learning through imagination and self-discovery should be emphasized more than teaching in creative music education.

Newton & Beverton (2012) mentioned that creativity is more correlated with music and visual arts education than other disciplines. Webster (1900) defined this creative process as "creative thinking". Hence, creative thinking is required to integrate in the process of musical understanding through teaching and learning for the development of musicianship in music education. This dynamic mental process is more valued than the product on musical creativity in music education. It is not solely limited to the product with high level technical skills in the music performance (Webster, 2002).

Creative thinking plays an important role in music related activity such as improvisation and brand-new musical ideas will be generated through modification and evaluation. Csikszentmihalyi (1999) has the similar view that creativity arises with the combination of musical knowledge and psychological disposition. Kleinmintz, Gldstein, Mayseless, Abecasis and Tsoory (2014) showed higher divergent thinking scores from creative musicians who play improvisation, in relation to mediate effect of idea evaluation. Lewis and Lovatt (2013) states that improvisation is a process of transformation from abstract personal feeling to concrete musical ideas during performance, that indicates the creative thinking in music learning.

Music educators developed music curriculum including improvisation, creative music appreciation, multimedia musicianship projects, that stress the creative expression in music learning to promote the musical creativity. It involves creative music making that brings student a positive experience from learning by doing, instead of being a passive listener or a follower. The active engagement in the creative collaboration helps to build up the musical thinking from the traditional view to the construction of knowledge in new perspectives and the process of creative thinking may lead to innovation (Amabile, 1988).

Professor Leak (2014) from University of Illinois mentioned that art is an efficient learning tool in the article of Richmond Art Centre (Fountain, 2014). It is shown that computational thinking is the fundamental mindset for engineering students (Gross, Kim, Schlosser, Mohtadi, Lluch & Schneider, 2014). Most of students are not very confident in sketching the ideas. However, after they try to communicate their own ideas through quick sketching, students found that quick sketching could be considered as a desirable tool which could help them to visualize the ideas. Drawing is highly correlated with the originality (Kozbelt, 2004). As such, it is observed that engineering and art are closely interrelated and they were not completely separate disciplines as traditionally perceived (The New York Times, 2014). It reveals that new ideas generate from artwork, which are not built on definite rules. This non-routine thinking process may lead students to combine parts and discover new possibilities (Ulger, 2018).

Students who learn through creative arts activities enhance the skills in aesthetic inquiry and reflective thinking (Lampert, 2006) and it is suggested the education should be infused with the arts (Deasy, 2002; Richmond, 2009). The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2011) stated that education rich in arts maximizes opportunities for learners to engage with innovative thinker and gain confidence in critical and creative thinking.

2.6 Creative process as "Creative Learning Spiral"

The proposed model in this research is based on the framework of *Creative Learning Spiral* by Mitch Resnick, a professor in the MIT Media Lab and the director of the Lifelong Kindergarten

Group at MIT (Resnick, 2017). Resnick defines the *Creative Learning Spiral* as the process of design and applies the spiral of *imagine*, *create*, *play*, *share* and *reflect* in a continuous loop, to stimulate students in drawing on their personal experience and prior knowledge to discover new problems as creative thinkers (Resnick, 2007). This learning process is different from the traditional way of learning. Traditionally, students are conventionally being invited to design, create, experiment and explore in the learning process based on the assigned topics. Resnick's *Creative Learning Spiral* includes all the mentioned key elements and place more attention on the spiraling process, that paves the way for students to imagine new ideas and further refine them in response to the everyday problems, which helps to nurture students as lifelong learners.

Resnick (2017) points that it is worthwhile for educators to explore new ways to benefit students' learning. He shared that he and his MIT research team organized a robotics workshop for a group of students ranging from age 10 to 13. The content of this workshop was to invite students to invent a new object which could improve everyday life. The style of learning experience in this workshop was student-centred. Wide variety of materials and tools including the *Scratch* programme, craft materials, LEGO bricks, magnets, glue guns etc. were provided. Resnick and his team evaluated the workshop as very successful due to the following observations:

Imagine	• The combination of high-tech (computers and related programme/software) and low-tech (paper, felt, glue) materials helps to boost and spark the imagination of participants.
Create	• Participants have enough time to explore, create and experiment the ideas.
Play	• Figure out the problem when the participants have the trial run of their inventions.

Share	• Participants were well supported by mentors with good communication. • Open-ended questions were raised by mentors • Try out and share new ideas with peers
Reflect	• Participants were eager to ask questions for more innovative ideas to improve their products and solve their problems they encountered
Imagine	• Participants were supported and followed their individual interests, leading to diversity of the project. • Their passion motivates them to develop new ideas and way of thinking.

Table 2.1: Observation in an example of a robotics workshop (Resnick, 2017)

It was found that this learning experience comprehensively aligned with the framework of *Creative Learning Spiral.* All the participants went through all stages in the learning spiral. They created their own ideas followed with their imagination and interests, tried and experimented their products with alternatives as well as getting inspiration from peers and mentors. Resnick (2017) realizes that there is a close relationship between imagination and creativity. He points that human creativity is rooted from an individual's power of imagination and it is a step beyond imagination. More variety of new ideas were generated from their hands-on experience. It is explicitly proved that creativity takes place and students are able to develop and refine their creative thinking.

Resnick (2017) assures that students may develop creative thinking and learn best through participating in projects, which are based on their own personal interests and passions. He also spots that different students may have wide variety of interests. In order to motivate all students to work on the projects meaningfully, technology is required to support a wider range of project types. It is disputable to judge the appropriate amount of screen time that children spend on electronic devices, and thus bring the concerns about the role of new technologies in education. In order to intimately link between playing and learning, it is suggested that parents and educators should focus more on how the children utilize the high-tech learning tools and try to maximize the creative time to develop the creative thinking (Resnick, 2017). It is more important to measure the screen time in quality, but no point to focus on quantity. Different kinds of devices or teaching materials are encouraged to apply in classroom teaching and learning in order to stimulate students' imagination. In order to stimulate creativity, designing tools and material selections are essential from a conceptual process to a practical process (Resnick, 2017). It is crucial for student to design and create something new though using interactive and interesting teaching materials and tools, but not only limited in doing the set task.

2.7 Human-centred Design Instruments (HCDIs)

The needs and abilities of the users are emphasized in human centred design. Norman (2005) stated that human-centred design is 'one design something for people with a deep, detailed knowledge of those people…' Buchanan (2001) stated that human-centred design should be highly focused on human beings during the design process. Manzini (1995; 2015) had the similar view that human beings should extend the capability, expand the cultural and spiritual possibilities for improving the life quality, but not only limited to survive. Human-centred design is considered as a creative exchange of knowledge, a combination of experiences and ideas between the designer and the other stakeholders, including the users, in production and consumption (Walter, 2005). Human-centred design principles are applied to a variety of social issues, leading to many public sector innovations (OECD, 2017), and they help to improve both usability and understanding. Baum (2016) stated that the human-centred design is 'an art of making things better for and with people'. It is worthy to draw attention on the mindset of HCDI designers as they are able to examine the constraints in reality and explore the possible range of conditions that human is able to function (Norman, 2005), but not expect the nonexpert users to learn how to control the devices.

Due to the radical technology development in the 21st century, human interaction was much more highlighted and the conception progressively shifted the focus from a traditional usage of a programming computer tool for a productivity enhancement to a more accessible and interactive interface for all walks of life, that helped to expand the scope and range of computer-mediated human activities for facilitating more sophisticated and unique tasks (Stephanidis, 2001). It is a practice to involve people collaborating on ideas that may create value for society. The main aim of the design is putting people first, where human experience, interactions and perspectives are accounted for throughout the process of creation. Creative minds from diverse disciplines are encouraged to work together to come up with ways of doing things differently to create impact (UNICEF, 2016). This type of participatory engagement involves co-creation, leading to inspiration and has an effect on our lives, and is obviously a kind of trans-disciplinary learning. Putting this philosophy into the education context, HCDIs may allow people from all walks of life to participate in music and help create solutions to problems in music education, without simply focusing on traditional composition and performance. A new direction in arts education should be taken, and the barrier for those who are not equipped with musical skill should be lowered, as they can also enjoy playing musical instruments and get involved in music making. The principle of a human-centred design instruments (HCDIs) is the technology, which is used in the design, should be adapted to person (Norman, 2008). The HCDI combines the world of technology with knowledge transfer, stimulating the imagination through the creative process and recognizing the potential of the interface to deliver personal aesthetics for unique innovation, leading to the aim of education – learning for life.

2.8 Makey Makey Invention Kit

Makey Makey is an invention kit, which is a small USB device that connects with conductive materials and transform them to be a touch-sensitive button and control objects on the computer screen (Silver et al. 2012). *Makey Makey* consists of a circuit board with a microcontroller, connecting the computer without installation of drivers or software and allows sending keyboard or mouse events to the connected computer (MIT Media Lab 2015). It has been used as a teaching tool in numerous research projects focusing on ideas generation through technology involvement for both students and elderly. Rogers and his team applied *Makey Makey* in a creativity workshop with a group of retired people between 60 and 90 years old (Rogers et al., 2014). It was learnt that most of the elderly people were willing to accept the challenges and invention occurred when they freely shared their ideas and their situated knowledge. Participants can creatively design a palpable and human-centred interface that allows both beginners and experts to get involved in music-making through linking the conductive objects with the provided alligator clips instead of using the computer keyboard. It showed that this project was able to inspire them to increase their motivation to learn more about technology. The participants were able to master the technology and generate diverse musical ideas through playing their own human-centred design instrument. The tool can thus encourage people from all walks of life to be more involved in creative technology through everyday experience. It shows that actively collaborating to play music together in a highly coordinated way with the application *Makey Makey* can lead to subsequent discussions, which helps to stimulate human's creativity in generating various ideas.

The project in this study was to assign students to design the human-centred design instruments for kids, adults and elderly with the application of combined knowledge and skills into real-world context through the use of the invention kit *Makey Makey*. Picture 1 below showed one of the human-centred design instruments (HCDI) that designed by the participants (Form 1 students) in this study. It aligns with the study from different scholars, showing students in a classroom setting can brainstorm their interactive and artistic ideas (A) collaboratively through mastering the technology, which acts as an experimental platform for students to participate in practical innovation through self-expression (Siemon D. et al., 2016), moving from STEM to STEAM education with the use of *Makey Makey*.

Picture 1 The design of one of the human-centred design instruments (HCDI) in this study

2.9 STEM and STEAM Education

2.9.1 STEM Education

STEM education is an integrated approach for developing the knowledge, skills and belief through inquiry-based learning in four areas namely Science, Technology, Engineering and Mathematics (Corlu, Capraro, & Capraro, 2014). Moore, Stohlmann, Wang, Tank & Roehrig (2014) mentioned that the framework of STEM education was classified into two categories: content integration and context integration. Content integration refers to the merge of the content in different STEM areas in a designed learning activity while the context integration refers to the learning and application with meanings through the use of the STEM content. It is observed that the latter one is in more advanced level but unfortunately high levels of skilled workforce and participation is crucial for lifelong stem literacy in the community. Many modern countries including United States (National Research Council [NRC], 2012), Australia (Office of the Chief Scientist, 2014), Korea (Park, H, et al., 2016) has already taken the lead to develop the STEM curriculum in recent decades. It is the global direction to strengthen the innovation development capacity of the future generation in order to raise the competitiveness in the contemporary world.

2.9.2 STEAM education

It is a disputable issue that the implementation of STEM education should move onwards to STEAM education in order to match the sustainable development of the education goals in 21st century. STEAM education combines the disciplines of Science, Technology, Engineering, Arts and Mathematics. Yakman (2008) was one of the early founders of STEAM, who suggested a framework in adding arts (A) to the foundation of STEM Education. She defined STEAM education in five levels, which are lifelong learning, integrative learning, multidisciplinary learning, discipline learning and content specific learning (Yakman, 2008). Korean researchers hold a similar point of view towards STEAM education as integrative learning, which encourages students to learn the overview of different subjects and their corresponding relations. As arts-infused education is highly recognized in developing creativity (Park & Ko, 2012), integrating art-related skills in teaching and learning activities of STEM education may support the learning domain in STEM, switching the learners from computational thinking to creative thinking. STEAM education is considered as holistic education, ranging from professional learning to lifelong learning. Art stimulates students to converge the gained knowledge and personal experience in learning and helps to build up the inquiry skills to questions of scientific and social issues in reality (Biffle, 2016). This kind of sustained learning in adaption to the needs and changes in the fast-paced society is essential for solving the real-world problems.

2.9.3 STEAM education requires the process of creative production and enhance the 21st century skills

It has been suggested that STEM education should shift towards the implementation of STEAM, in line with the sustainable development of education goals in the 21st century. STEAM concept was also promoted in a STEM to STEAM program, organized by Rhode Island School of Design (RISD) in the United States, that placed Art and Design at the centre of STEM (RISD, 2013). John Maeda, president of RISD (2008-2013), believes that art is the main element in innovation in this century. Maeda (2013) stated that designers and artists created objects that were more human and efficient to meet the practical needs in this world. He realized that the 21st century skills including creativity, problem-solving and critical thinking skills, which were generated through the design process, was the core part to remain competitive and innovative. Pure knowledge is not enough for living in the evolving society. Based on the foundation of STEM, arts (A) is encouraged to incorporate into students' learning across the four mentioned disciplines in STEM education. Both art and science share the same value of discovery (Biffle, 2016). Combining the aesthetic sense and the sensory experience, it stimulates human's thinking and the own identity is formed. Taken the infused-humanity into consideration, unique ideas will be produced and these ideas represent the output of creativity (Diehl and Stroebe, 1987).

Educators from Rhode Island School of Design (RISD) and the National Technology Leadership Coalition believe that "Art" in STEAM education bring learners extra benefits in child development, such as cognitive and emotional development, instead of being a supporting role in STEM education (Ge, Ifenthaker & Spector, 2015). Students are not expected to limit their learning solely in scientific concepts anymore. In the past, science and technology played an important role in the society, that had directly changed the way we live. Ballard (2017) stated that the standard of education should be level up with the rapid advancement of technology, which provided young learners opportunities to think forward in tackling the root of the problems that we face daily and channel the creativity into productive ideas for solution, instead of only teaching students individual disciplines (PC World, 2017). The arts-infused learning nurtures learner's creativity and provide them opportunities for self-expression. It trains learners to be divergent creative thinkers, who are passionately influenced by an interest, and make connection across disciplines, rather than learning one specific area in a rigid way (Dail, 2013; Eger, 2013; Root-Bernstein, 2003).

In STEAM education, students are expected to learn the expert knowledge not only within discipline, but also trained to break the boundary and make connection between disciplines based on one individual's knowledge, experience and sense through art-infused education. When bringing all these mentioned elements together, students may connect a deeper understanding in a holistic manner through integration of disciplines. It may lead to some newly constructed ideas which are resulted from the creative process. This connection is crucial for fostering the creativity and innovation in students' learning as well as the development of the skills in problem solving and innovation in reality, which are aligned with the 21st century skills (Ge, Ifenthaker & Spector, 2015).

2.9.4 Implementation of STEAM-based activities in Hong Kong

In Hong Kong context, STEM education was first proposed in 2015 and to be further highlighted in the 2016 Policy Address, concerning the renewal of the school curriculum for equipping Hong Kong students with necessary knowledge to nurture students' critical thinking across disciplines. It is promoted to raise the students' ability in integration and application of knowledge through Science, Technology, Engineering and Mathematics for solving authentic problem in the everyday life. This kind of learning process may facilitate the life-long learning and serve to be a well-rounded individual, which is the ultimate goal in education (Education Bureau, 2015).

For the implementation of both STEM and STEAM-based acitivities, it varies in large extent in different types of school in Hong Kong, depending on both hardware and software. The qualification of educators and the resources are the main concern to evaluate the effectiveness of the STEM education. An article from MingPao (2018) stated that school principals in Hong Kong still focused on teachers' academic qualifications, rather than the application of the pedagogical approaches. Moreover, teachers who have been employed by schools for a number of years found it hard to follow this educational trend and tended to delegate the teaching of STEM program to STEM-expert teachers. As a result, some primary schools have hired up to six secondary level science teachers to teach STEM subjects. The lack of coherent education policy has led to insufficient teaching expertise when implementing the lessons. Thus, an enormous gap between education policy and actual practices has thus been identified in the promotion of STEAM education. To strive for a better result of the reformed education policy, the Education Bureau (EDB) is prepared to provide each secondary school a one-off subsidy of $200,000 to support the school-based programmes and teacher training for broadening the knowledge and the continuing professional development in STEM (Policy Address HKSAR, 2017).

2.9.5 Prospects and Challenges in STEAM Education

2.9.5.1 Prospects in STEAM Education

It is noticed that STEAM education starts to be popular in the educational system and it is now implemented across the globe for a number of reasons:

i) Transdisciplinary Learning as Knowledge transfer to life skills through STEAM education

The goal of transdisciplinary learning is considered as the understanding of the world at present and it cannot be accomplished in the framework of disciplinary research (Nicolescu,1997). It is observed that STEAM education supports transdisciplinary practices, which closely match the current educational trend.

STEAM education emphasizes students to learn and be knowledgeable across wide range of disciplines. It aims to tie different subjects together and educates students to integrate the knowledge in investigating the problems in variety of perspectives (Nicolescu, 1999; Quigley & Hero, 2016). Nicolescu (2002) affirms that transdisciplinarity is essential for solving complicated problems and STEAM education could offer innovative solutions to contemporary problems. STEAM is considered as a kind of transdisciplinary learning, which is not a brand-new idea in education. International Baccalaureate (IB) program and Montessori Education adopt transdisciplinary approach to curriculum integration, without setting boundaries among disciplines in order to organize the teaching and learning holistically in the context of real-world problems through the inquiry process, as life almost never fits into a single and independent discipline (Sherrill, 2012). This direction aligns the view with Nicolescu (2013), who stated that transdisciplinary learning leads to four foundation pillars of education in the UNESCO report (Delors at al, 1996) – 1. learning to know 2. learning to do 3. learning to live together and 4. learning to be. It is shown that STEAM competency highly corresponds to transdisciplinarity, which supports students' creative thinking and coherently integrate ideas from various domains to create solutions for problems existing in the society in any disciplines (Mishra, Koehler and Henriksen, 2011; Kim and Bastiani, 2017).

Transdisciplinary studies initiate from a particular problem and bring the knowledge of the related disciplines for problem-solving (Meeth, 1978). Problem-based learning is one of the pedagogies to support transdisciplinary learning, leading learners to different disciplines and thus helps them to nourish the capability in transferring their learning to multiple disciplines (Liao, 2016). Teachers usually structure a problem and students are given opportunity to integrate the situated knowledge among disciplines, extract the mutual elements and synthesize them as a solution for solving the problem (Ertas, 2000; Ertas, Maxwell, Rainey & Tanik, 2003; Nordahl, & Serafin, 2008). An ideal of transdisciplinary learning is expected to be in the boundaries of the problem but should not be limited to the boundaries in the disciplines (Nordahl, & Serafin, 2008). As such, STEAM education encourages learners to think and learn thoroughly for everyday life.

Yakman and Lee (2012) stated that students' ability in transferring knowledge with higher order thinking among disciplines was enhanced under STEAM education. It aligns the view from Well (2008), who mentioned that with the element of arts (A), students applied knowledge from different domains with personal creative pursuits on focusing the designed-based problems in STEAM education. Through the design process, it engages students to learn in needed basis and encourages students to access multiple disciplines and perspectives, which is central to transdisciplinary practices. In the research conducted by Kim and Bastiani (2017), the game design project brought students to be engaged in problem solving "interestingly". It is a kind of design-based learning to develop students' STEAM competencies. The participants clearly demonstrated their understanding of simple mechanical system and the connection of video recording devices through the process of the game design for integrated curriculum – from "learning to know" the discipline-specific knowledge to "learning to live" for problem solving. These students referred to their personal experiences that most of the existing educational games were not fun enough for students to learn. They reflected that they aimed to design the game be more interesting for players to learn. They self -located the root of the problem (Kim, Tan & Bielaczyc, 2015) and found the need to create a new pattern of games through the design process (Long, 2012). As such, the students served as the active innovators with empathy, instead of being passive users, incorporating the learnt knowledge and skills in cross-disciplines, embedded with their creativity into their game designs through the process of "learning to do" (Nicolescu, 2013). STEAM competencies were obviously developed through the transdisciplinary approach. Students learnt the expert knowledge not only within disciplines, but also trained to dissolve the boundary and make connection among disciplines based on one individual's knowledge, experience and sense through art-infused education. Through the participation of the game design project under the transdisciplinary approach, a deeper understanding in a holistic manner through integration of disciplines was shown (Hsu and Wang, 2010; Salen and Zimmerman, 2006) and newly constructed ideas with meaning in the real-world context were resulted through the creative process, shifting from the computational thinking to human-centred learning. This connection is crucial for the development of the skills in problem solving and foster creativity and innovation in students' learning.

ii) STEAM jobs in big demand in future

From the source of 13 Economics and Statistics Administration (2011), the growth of STEM jobs was three times higher than that of non-STEM jobs. From the data of the US Department of Commerce (2012), there was an increase of 17% of job offerings that were included the elements of science, technology and math in 2018, while there was only a growth rate of 9.8% in other job fields, which was nearly a double of growth in comparison to the non-STEM fields. The US Department of Education estimated that there is a 14% increase of STEAM related jobs from 2010 to 2020, which is 5-8% higher than the other job sectors (PC World, 2017). Institute of the Future predicted that 85% of jobs by 2030 will be doing the content that have not been invented.

It is believed that most students in this generations should get themselves prepared to join the workforce that requires creativity and innovative mind for solving the real-world problem (Henriksen, 2017; Dell'Erba, 2019). The rising demand of STEM and STEAM job is obviously seen.

iii) Develop creative thinking through STEAM Education

It is observed that STEAM education and design-based learning reveals a close connection among transdisciplinarity. A series of ideas from several disciplines are generated through divergent thinking and new insights will be found to reach the problem. The synthesis skill in transdisciplinary learning is complex, but with high theoretical and pedagogical values. It defines as a skill bringing the knowledge, experience, sensory impression and feeling altogether in the creative process and thus generate this kind of subjective thinking into new ideas in a unified way (Root-Bernstein & Root-Bernstein, 1999).

STEAM education is a kind of transdisciplinary learning. Creativity occurs when new ideas are formed or partly generated from the existing conventional ideas at multiple levels. Mitchell (2005) states that it is not only drawing all concepts across disciplines together in true transdisciplinary learning. It is recommended to break down the traditional boundaries of the discipline for new knowledge creation. Henrkisen and his team (2015) clearly explained synthesis of meaning is the gathering and development of knowledge across diverse sources while creative synthesis integrates the knowledge and sense in a cohesive manner. The type of synthesis in transdisciplinary approach is the latter one (creative synthesis) which transform the new ideas from the combination of the sources (synthesis of meaning) (Henrkisen, DeSchryver, Misha, 2015).

2.9.5.2 Challenges in STEAM Education

Surprisingly, it is ironic that STEAM education is still not very popular in school or college. STEAM education cannot be dominated around the globe. In the U.S. educational system, it is difficult for educators to implement without a standardized curriculum (Fusarelli, 2004). It was seen that STEAM education was only popularized with a growth of 0.8% as many of the educators and students still prefer the route of learning sticking with "traditional" subjects in separate discipline, such as language. In Asian context, such as Korea, the majority of teachers view that STEAM education is necessary to match the demand of the 21st century. However, it is lamentably that only around 18% of teachers are able to implement the STEAM lessons (Shin, 2013).

In the research conducted by Geng, Jong and Chai (2018), half of the in-service teachers are not ready for the STEM education due to the lack of knowledge and pedagogical instructions. This data was collected from the teachers who voluntarily participated in the STEM educational seminar and it was proved that these participants were intrinsically interested in STEM. Other than that, only 5.5% of the teachers, who filled in the questionnaire about the preparation towards STEM education, mentioned that they were ready to implement STEM lessons in classroom setting. As such, there should be more than half of the teachers in the field were not ready for the STEM education and not capable to move forward to STEAM education in reality.

It is clearly shown that inadequacy in education pathway in STEAM is one of the factors that makes STEAM education hard to be dominate in the education system and the current workforce cannot support with necessary skills and knowledge.

2.10 Summary

To conclude, the literature highlighted that creative thinking plays a very critical and crucial role in STEAM education and it benefits students' engagement and motivation in learning. As such, students participate in STEAM education are able to think trans-disciplinarily through the deeper conceptual learning and broader practical learning. However, the literature also addressed the huge gap in the inadequate teacher training in STEAM education for teachers to embrace this inquiry approach in teaching in fostering students' creative thinking.

III. RESEARCH DESIGN AND METHODOLOGY

This chapter includes the purpose of the study, research design, methodology approach, participants, instrumentation, data collection and analysis procedures.

3.1 Purpose of Study

The purpose of this study is to examine creative thinking and learning in the STEAM-based activities by using the invention kit *Makey Makey* as a Human-Centred Design Instrument (HCDI), which is a creative making with knowledge, experience and new ideas between designers (students) and users (kids, adults and elderly) to accommodate the needs of the target groups. Many scholars (Amabile, 1996; Beghetto & Kaufman, 2010; Sawyer, 2011; Kaufman and Baer, 2012) agreed that students' engagement and stages of experience from everyday life are crucial in creative thinking. As such, the goal of this research was to gather data about the Hong Kong students' involvement and attitude in participating the STEAM-based activities in designing Human-Centred Design Instruments (HCDI) with the use of *Makey Makey* for different age groups (kids, adults and elderly) in the classroom settings as well as their application of their creative thinking skills in the real-world context.

Adding the element of art (A), which provides an opportunity for students to illustrate the academic concepts in a creative and imaginative way through inquiry-based learning, is the major direction to implement the STEAM class. The curriculum design of the STEAM-based activities in the participating school in this research paper was developed by the researcher and the teacher in-charge of the STEAM project from the participating school. The strategies for designing the embodied curriculum in this study were set for students to develop creative thinking and transform new knowledge across disciplines to create a meaningful context in everyday life through metacognition, as well as to further construct pedagogical framework for teacher training and conceptualize the Learning-thinking model in STEAM education.

A self-funded pilot study with all human subjects' permissions was conducted in a mixed-method approach, which was used to gain a complete understanding of the complex process of facilitating creative thinking, from creative learning to real world application, through STEAM education. The overview of the data sources is shown below:

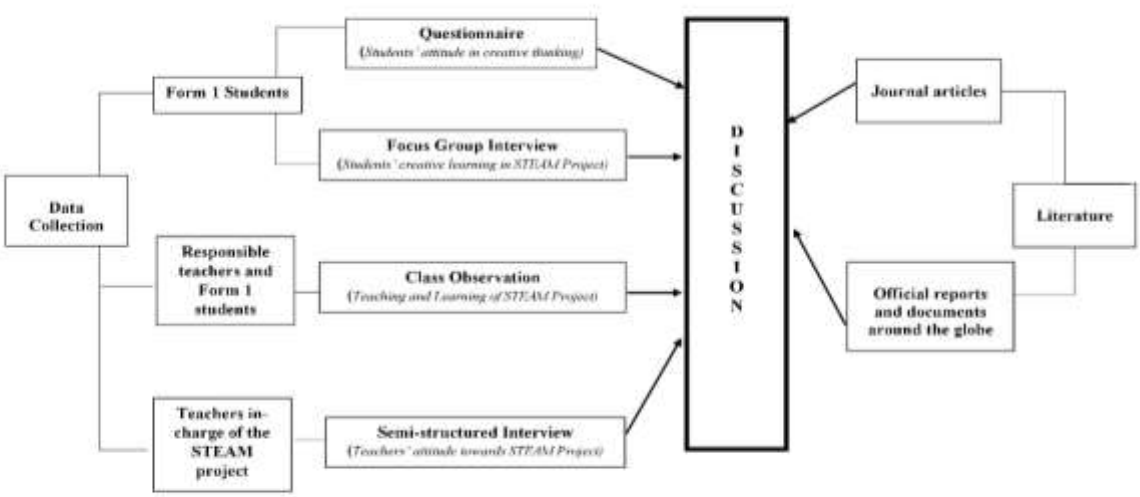


Figure 3.1: Overview of Data resources

3.2 Research Design

A design-based research approach was taken, which was focused on the reflective inquiry in an innovative learning environment (Brown, 1992; Collins, Joseph and Bielaczyc, 2004). This research study was the collaborative effort among the researcher, teachers who are in this STEAM project team from the participating school, kindergarten students, adults and elderly who served as the users of the human-centred design instruments (HCDIs) to support the application of combined knowledge and skills into real world contexts with meaning through the HCDI design activity. Data were collected via three sources: 1. two online questionnaires with pre and post intervention, 2. two class observations, 3. one individual interview with the teachers in-charge of the STEAM project and 4. three focus group interviews with students who design the musical instruments with the set of constraints of the respective age groups (*ie Group I: Kids; Group II: Adults; Group III: Elderly*) in the STEAM project.

The research project was implemented in two stages in a Hong Kong secondary school across two consecutive academic years: 1st stage (October – December 2017) and 2nd stage (December 2018 – January 2019). The study was conducted in two stages through the use of the invention kit *Makey Makey*. Information about the basic use of invention kit *Makey Makey* and making simple music instrument with *Makey Makey* are provided for the participants by the teacher in-charge of this STEAM project.

The targeted participants were two batches of Secondary 1 students. They were selected for participating in the STEAM project, which was one of the components in the school curriculum. Students in the class will be divided into several groups in each class to participate in a series of activities in the classroom setting, ranging from the introductory course of learning how to use the Makey Makey Tool Kit, design the musical instruments with the Makey Makey Tool Kit, improvise the tune with the designed musical instruments and create the Human-Centred Design Instruments (HCDIs) for different age groups in the society. The students were assigned the target of designing the human-centred musical instruments in groups for adults, kids and elderly. The curriculum design and the setting of the STEAM class were divided into 3 parts across 8 weeks continuously (1 hour per week). It is summarized as follows:

Stage	Aim

1st stage - Introductory stage (2 hours)	• To deliver the students the invention kit *Makey Makey* and the software *Scratch* • To provide opportunities for students to get hands-on experience coding the music notes and programming the sound by connecting the alligator clips from *Makey Makey* with the online programming software *Scratch,* thus creating a *Makey Makey* instrument.
2nd session - Exploration stage (4 hours)	• To explore the conductive materials in groups and generate ideas for the HCDI with the *Makey Makey* Tool Kit. • To combine the collaborative ideas and design the HCDI with the set of constraints for the respective age cohort.
3rd session - Experimental stage (2 hours)	• To show how the designed instruments function and how to apply them to the targeted age cohort through simple demonstration. • HCDI trial run at the kindergarten.

Table 3.1: Summary of the three stages of the STEAM project

3.3 Methodological Approach

To achieve the above-mentioned aims, this research used a QUAN-QUAL model, where quantitative and qualitative are weighted equally (Roberts, 2004). Mixed method was considered as an appropriate way to balance the strength and intrinsic weakness of the results in both quantitative and qualitative measurement (Smith, 2006). Through the comparison and interrelation of the quantitative and qualitative data sets, it helps to provide results in greater breadth and depth with the application of the quantitative data to validate the qualitative analysis, combining the summary of the large amount of data statistically in a broad perspective through questionnaires and cases to study in depth from the viewpoints of participants with rich descriptive details through open-ended interviews and observations (Strauss and Corbin, 1990; Clark, 2002.)

The research adopted multiple methods, including questionnaires, interviews and class observation to gather the views in the perspectives from both teachers and students, who participated in the STEAM project through designing HCDI for different age cohorts in regard to the altitude change of students' creative thinking, the benefits and challenges that both teachers and students encountered in the series of experiential activities in order to determine the role of teachers, and further explore the direction of the curriculum design in STEAM education for teacher training in order to conceptualize and enhance the efficiency of the Learning-thinking model in STEAM education.

Use of multiple data sources from various perspectives act as a form of triangulation (Creswell, Plano Clark, et., 2003). This research study is in triangular design for "obtaining different but complementary data on the same topic" (Morse, 1991) in order to have the best understanding of the research problem. It is a process to look for the consistency of findings through the repeated verification across various data collection methods and also provide multiple reference points that informed the analysis and interpretation of the data (Patton, 2002; Stake, 1995). It allows flexibility that can extend the line of inquiry to interpreting multiple sources, thus providing a more focused view of this complex phenomenon in a natural setting and filling the gap in the acquired related data (Creswell, 1998). Given this is an exploratory research, different data sources are triangulated for strengthening the quality of the research on different grounds, in order to build a coherent justification and raise the validity of the study.

3.4 Data Collection and Measurement

3.4.1 First Stage – Quantitative and Qualitative Study

In the first stage of the data collection, six classes of Form 1 students (n =249) were arranged to create human-centred musical instruments (HCDI) for different age cohorts including kids (aged 3-6), adults or elderly people (aged over 65) in the STEAM project as the first stage to examine the altitude change in the level of creative thinking. Students were randomly divided into several groups and participated in a series of activities in the classroom setting, ranging from an introductory section on “how to use the *Makey Makey* Tool Kit” to an experimental stage on “how to design and create the HCDI with the Tool Kit for different age groups”.

a) Quantitative Study: Questionnaire

Questionnaire were set at the first stage to focus on the measurement of altitude change of creative thinking in STEAM education in a quantitative way. It was set as a self-evaluation for each student to measure the altitude change of the divergent thinking that takes place in the creative thinking process.

The Runco Ideational Behavior Scale (RIBS) was used with modifications from the framework of the attitude towards creativity in the idea creation process from Runco et al. (2001) to direct the investigation of the research question ‘How do students change creative thinking through human-centred musical instruments (HCDIs) in STEAM education?’. The ideation behaviour of the students can be examined to gain a better understanding of their everyday creativity. For the original version of Runco Ideational Behavior Scale (RIBS), please refer to the Appendix 1.

The RIBS can be used as a criterion of creative ideation for both children and non-professionals through a self-report measurement of personal assessment of creativity. The scale contained 21 modified close-ended items about ideation as product and divergent thinking, which were assessed using 5-point Likert scales ranging from 1, 'strongly disagree', to 5, 'strongly agree'. Brooke (1996) mentioned that Likert scale is able to capture the expression of the attitude by indicating the degree of in favor with the statement on a 5-point scale by the respondent and it may provoke extreme agreement or disagreement among respondents.

The questionnaire was classified into four main dimensions of (1) Originality (Q 1, 5, 7, 10, 17 and 21), (2) Flexibility (Q 6, 8, 14, 16, 19 and 20), (3) Fluency (Q 2,4,12, 13, 15and 18) and (4) Elaboration for creative thinking (Q 3, 9 and 11). All of which were considered as creative thinking strategies that reflected students' abilities in the process of brainstorming and connecting ideas, eventually leading to the creative product (Guilford, 1950; Gorder, 1980; Webster, 1994; Runco et al. 2001; Kharkhurin, 2008). The RIBS scale was further correlated with happiness, creative ideation and locus of control. It was found that happiness was predicted to be correlated with creative ideation (Pannells and Claxton 2008). In order to ensure the reliability of the questionnaire, the questions order was randomly mixed up. For the full questionnaire, please refer to the Appendix 2.

The items in the questionnaires reflect openness to divergent attitudes, which support creative thinking (Runco et al. 2001). This questionnaire was carried out to determine whether there were any changes in attitudes from students towards creativity between the control group without constraint (adult group) and the experimental groups with constraints (children and the elderly). Attitude changes regarding creativity of both groups can also be simultaneously assessed to ascertain whether there is any significant difference in the four dimensions through HCDI in arts education.

Procedures of Questionnaire Administration

A total of 267 Secondary 1 students from a Hong Kong secondary school have been invited to participate in this research and 249 students agree to participate in both pre-questionnaire and post-questionnaire. Before the questionnaires were distributed, the project in-charge and his team members were briefed on the purpose and procedures of questionnaire administration. All questionnaires were shared in the google drive and students were expected to fill in the online questionnaires in the first (*Pretest*) and last class (*Posttest*) of the STEAM project. Students rated themselves twice in the same form as the STEAM project was recorded.

b) Qualitative Study – Interview

One open-ended interview is conducted with one teacher in-charge to explore their perceptions of the students' engagement and the role of the teachers in the STEAM project using the *Makey Makey* toolkit in a qualitative way.

The main aim is to let the teachers express further based on their own thoughts and standpoint. The interviews questions focus on the collaborative conversation in relation to teachers' daily practice in three main stages, namely preparation stage, teaching stage and reflection stage. The content of the interview is mainly about the concrete situation of the interviewees including the curriculum design, preparation of teaching materials and lesson planning.

Follow up questions including their judgement to the value and the challenges of the human-centred design instruments project under STEAM education are raised spontaneously in order to have a more in-depth knowledge production for filling the research gap and provide answers to the research questions, which is able to reflect the reality. It allows the flexibility that can widen the line of inquiry to interpret multiple sources for gaining a better focused view of the complex phenomenon in the natural setting and fill in the gap of what the related data are acquired (Creswell, 1998). Considering the original research question, additional insights about motivation, learning environment, evaluation and assessment in STEAM project are further explored during interview.

Procedures of Interviews

One teacher who is the in-charge of the STEAM project are invited for the interview. Information sheet and interview questions are sent to these two involved teachers after they completed the whole STEAM project. It was conducted as a semi-structured interview and was set in the style of reflective open-ended questions. The interview was conducted after class in school campus and the duration of the interviews were around 20 minutes.

c) Qualitative Study – Class Observation

Two observations are conducted in this research study. The main aim is to explore the teaching and learning practices of the STEAM project in classroom setting. One class observation was arranged in the exploration stage of the STEAM project in the secondary classroom to investigate the feasibility of incorporating Makey Makey into the STEAM curriculum. Another class observation was the human-centred musical instruments trial run, which was for the analysis of knowledge application in the real-world context. It was taken place at kindergarten and young children who aged 4-5 years old were invited to play the human-centred musical instruments designed by the Form 1 students. It is an additional opportunity for researcher to convey an interest about the hands-on experience of the participants as well as an important element of rapportbuilding with the participants for the development of a temporary relationship between researcher and participants (Hays & Singh, 2012).

A more detailed lesson plan was presented as follows (Table 3.2):

Lesson 1-2 (60 minutes per lesson)	**Task: Create a *Makey Makey* Piano instrument** ❖ Introduction • Play the video and introduce *Makey Makey* • Use *Scratch* to code the notes produced when different notes are pressed • Teacher briefly explains the codes (most codes are given to the students) • Students try to play music using the assigned key in scratch ❖ Making the instruments • Student use a piece of a white paper and some aluminum foil to make the notes of a piano • Connect the alligator clips to the aluminum foil keys on the piano • Students try out their own made piano and may improvise short tunes with the use of *Makey Makey* through the online program *Scratch*
Lesson 3-4 (60 minutes per lesson)	**Task: Create own *Makey Makey* Musical instrument** ❖ Discovery/Exploration Stage

	• 5-6 students in a group • Bring the prepared materials and try out different conductive materials with the connection of Makey Makey • Discuss and generate ideas for the design of the musical instruments • Set up the own kit with the desired materials • Try to improvise short tune with the newly designed musical instruments ❖ Collaborative Performance Stage • Play a song in group as an ensemble with their newly designed instruments in the class • Students share their experience and give feedback to the performance/design • Vote for the best performing group at the end
Lesson 5-6 (60 minutes per lesson)	**Task: Create Human-Centred Musical Instruments (HCDI) for Different Age Cohorts** ❖ Idea Generation • Form students into groups and discuss the characteristics of different age cohorts (ie Kids, Adults and Elderly) in terms of personality, level of musical knowledge, diversity of skill sets, level of experience and preference in technology

	• Each group is responsible for one targeted age cohort.
	• Encourage students to concern the particular needs of each targeted age cohort.
	• Discuss the ideas in groups and set the constraint of the respective age cohort.
	• Combine the collaborative ideas and assign students to design the musical instruments with the connection of *Makey Makey* kit by using different prepared materials for different age cohorts
	  ➢ Group I: Kids
	  ➢ Group II: Adults
	  ➢ Group III: Elderly

Lesson 7-8 (60 minutes per lesson)	**Task: Experiment and demonstration** • Present the innovative ideas in groups after collaborative discussion • Explain the rationale how the newly created instrument fits the target group • Show how the designed instruments function and how to apply on targeted age cohort through simple demonstration For eg. The 'Kids' cohort will be arranged to HCDI trial run at kindergarten and invite the young children to play the instruments.

	• Reflection on the process of creating Human-Centred Musical Instruments (Self-evaluation in creative thinking) • Teachers give comments to each group after presentation.

Table 3.2: The basic outline of lesson plan of the STEAM project

Procedures of Class Observation

The two observations were taken place in lesson 4 and lesson 8 of the STEAM project. One Form 1 class (n=42) was involved in the study. Each class lasts for 45 minutes. The observation was conducted in a naturalistic setting with no adjustment made by the teachers or researchers. It was video-recorded for analysis of the behavioral patterns of the participants and to establish how the two kindergarten classes (n=30) students, as the users, enjoyed and learnt through the HCDI with the guidance of the Form 1 students as the creators. The presence of the researcher is visible but act in the role of a non-participant in the class.

3.4.2 Second Stage – Qualitative Study

The class arrangement in the second stage of this research was similar as the one in the first year. In the second year, another six classes of Form 1 were arranged to design the human-centred musical instruments (HCDIs) in the STEAM project, which last for six weeks. The students were divided into 3 groups namely 1. Kids; 2. Adults; 3. Elderly. Three focused group interviews with students (*N*=15) who designed the HCDIs for different age groups (Kids, Adults and Elderly) were conducted after their participation of the STEAM project, in order to deepen the understanding about the process of their creative thinking and locate the benefits and challenges that they encountered under STEAM project in a qualitative way.

a) Quantitative Study: Interview

Focus group interviews were conducted solely by the researcher. The interview questions were designed according to the five stages of the framework of the Creative Learning Spiral (Resnick, 2007), namely as Imagine-Create-Play-Share-Reflect-Create. Specific lines of inquiry were pursued with the participants interviewed (Patton, 2002) based on what they had encountered in each of the stage in the Creative Learning Spiral. Follow up questions were shaped by the responses from participants. Longitudinal approach was applied to observe and document their learning and design process. The interviews aim to explore the students' creative learning experience in designing the human-centred musical instruments (HCDI) in the STEAM project and their perceptions in being a designer of a product for a specific target group in a real-world context. The students were also asked about the perspectives on fostering creative thinking and learning in the classroom in order to have a more comprehensive understanding of the students' engagement in the STEAM project using the *Makey Makey* toolkit in a qualitative way. These interviews were intended to triangulate the quantitative study concerning the students' attitude change in the level of creative thinking and the perception towards the creative thinking and learning in the STEAM project from teachers' perspectives, in order to further explore the direction of the pedagogical framework in STEAM education for teacher training in order to conceptualize and enhance the efficiency of the Learning-thinking model in STEAM education.

Procedures of Interviews

Three semi-structured interviews were conducted and it was set in the style of reflective open-ended questions. All the conversations were audio-recorded with permission for further data analysis and later transcribed verbatim by researcher. Students who designed the HCDIs for different age groups (Group 1:Kids; Group 2: Adults and Group 3: Elderly) were interviewed in three separate days. Selection of the final participants were based on their availability. Their participation was on a voluntary basis. All interviews were conducted after school in the school campus. The duration of the interviews were around 45-60 minutes. Questions used for the semi-structured interviews were attached in Appendix 3.

3.5 Method of Data Analysis

Unit of Analysis

Two levels of analysis, which were in school level and individual level, were conducted in this research study. At the school level analysis, data will be aggregated for organizational analysis to investigate the change of students' perception in creative thinking under STEAM education among all form 1 students in the participating school. At the individual level of analysis, individual teachers' and students' perception were considered as a unit of analysis. The interview with teachers represented a single case in critical sampling. It is most likely to provide the information, which directly brings impact to the studies (Patton, 2001). Other three focus group interviews with students were arranged in convenience sampling. They are selected subject to availability.

Analyses of Data - Questionnaire

The SPSS (Version 23.0) for window computer package were used for data analyses. Questionnaire is a quick research tool for researchers to collect data. Gillham (2008) stated that questionnaire could provide suggestive data and get information from a throng in an efficient way. It is a scientific and objective way to gather numerical data for calculation to represent a group of participants (Ng, 2015). The scientific result can produce accurate results, which helps to enhance the reliability of the investigation. It mainly focuses on data description and factor analyses for refining the research instruments.

i) Descriptive Analyses

Descriptive statistics such as frequency distribution and mean are used to provide the profile and of the participants and the attitude of their creative thinking in four different dimensions, which are originality, flexibility, fluency and elaboration.

ii) Factor Analyses

The paired and independent sample t-tests were employed to probe for any relationships and determine whether the difference in attitude towards creative thinking between the means of experimental and control groups was statistically significant, in response to the research question 2. The Pretest and posttest scores of both groups about their attitude in creative thinking were imported and calculated the difference between their retrospective pre- and post-ratings, reflecting the perceived impact of their creative thinking after designing the human-centred musical instruments. The participants' current levels of self-assessment were noted to create a common measuring indicator for pre- and post-assessments at the end of the related tasks, which could help to ensure consistency (Hiebert et al. 2011).

The treatment of the variables was processed by Pearson Product-Moment Correlation Analysis in finding the patterns of relationship between the level of creative thinking and students' learning attitude in STEAM education.

Analyses of Data - Interviews

The qualitative data from the responses from the interviewees were transcribed. Interview transcripts were analyzed and coded for summarizing the ideas from different participants. The thematic analysis model by Braun and Clarke (2006) was adopted to analyse the qualitative data in six steps.

i) First stage – Familiarization

The researcher started to get familiar with the raw data by listening the recording and review the accuracy of the transcripts. General notes were written as a guide to manage various possible answers to the research questions. It could also help to facilitate the coding process and theme identification (Wellington, 2000).

ii) Second stage – Codes Generation

Focus group interviews were coded with reference to the concepts generated from the guiding framework of "Creative Learning Spiral" by Mitchel Resnick (2017). The codes are the summary of the data in the format of phrases, keywords, sentences or whole answers.

iii) Third stage – Theme Searching

Conceptual themes would be generated for further analysis. The codes were assembled and examined for fitting into themes. The conceptual themes were the five stages of the spiral cycle in the creative process for developing creative thinking skills. They were namely as Imagine, Create, Play, Share, Reflect and back to Imagine.

iv) Fourth stage - Theme review

Respective identification symbols were organized, based on the patterns and themes which were identified in the process of clustering and categorizing the data in order to get an optimal understanding in the research (Tesch, 1990; Miles & Huberman, 1994). Some codes were in similar meaning and would be integrated for unified themes.

v) Fifth stage – Theme Development

Braun and Clarke (2006) explained to define and refine the theme through identifying the 'essence' of each theme. Tesch (1990) stated that this kind of data analysis process was considered as "data condensation". It aims to sharpen and focus the data for drawing and verifying the final conclusion of the study (Tesch, 1990; Miles & Huberman, 1994).

vi) Sixth stage – Reporting

In the last stage, this consolidation of data leads the researcher to interpret the concrete research findings and analyze the implication of the findings in response to the research questions raised in the study.

Field notes were gathered including the demographic information such as time and classroom setting. The descriptive notes were about the response from both teachers and students in the series of activities in STEAM project and the highlighted reconstructed dialogue. Key components including the creative ideas that raised by students, the attitude change of creative thinking from students, instructional strategies, school support and the response from the user of the human centred design instruments (HCDIs) were observed.

Analyses of Data - Observation

For observation, it was held as a non-participant observation that the researcher did not take an active part under scrutiny in order to keep neutrality. Field notes were collected (Cohen et al., 2008), including the information about the lesson content, classroom setting, teaching approach, numbers of students and related groupings, seating arrangement, teachers and students' behaviors and responses. Non-textual data such as pictures and video recordings were also applied for more in-depth description of the circumstances and interaction among participants who are experiencing the phenomenon (Patton, 2002; Strauss and Corbin, 1998). Koster, Pijl, & Nakken & Van Houten (2010) mentioned that observation is the tool to examine the interaction between teachers and students. Inductive approach was used by using the framework of Creative Learning Spiral (Resnick, 2017) in order to group the data and look for relationship. Textual codes were applied for identifying the specific data which may correspond to different set themes.

3.6 Sampling and Participants

A total of 264 adolescents (n = 264) from a Hong Kong secondary school have been invited to participate in this research. These students were arranged a task in designing the musical instruments with the Makey Makey Tool Kit and create the Human-Centred Design Instruments (HCDIs) for different age groups in the society.

In the first stage of the current study, 249 students (n = 249) out of 267 students were invited to participate in the questionnaire, which was set as a self-evaluation for each student to focus on the quantitative measurement of the divergent thinking that takes place throughout the creative thinking process. The questionnaires were administered to six Form 1 classes, with a total number of 42 students in each class. The participants in this research are all females in the age between 11 and 13 in a form of participatory design. They are all equipped with basic musical knowledge as all of them has attended elementary music classes in primary school. The reason of choosing this Hong Kong secondary school is its strong support towards STEAM education and a comprehensive STEAM curriculum is highly adopted to examine the level of creative thinking and learning in arts-infused education.

In the second stage of the current study, 15 students (n =15) were invited to attend the focus group interview. These students were divided into 3 groups before the STEAM project started, namely as 1. Kids; 2. Adults; 3. Elderly. They were assigned the tasks in designing the human-centred design instruments for different age groups users (i.e. Kids, Adults and Elderly). Each group consisted of five students.

3.7 Ethical Considerations

Ethical issues concerning the participants were considered during the data collection process. The present study was approved by the Human Ethical Review Committee (HERC) of the university. Though there were no known risk in participating this research study, a consent form was officially provided and signed by the participants including the teachers and parents before the research was conducted. A letter of collaboration, which stated all the arrangement and procedures of data collection, was also sent to the participating school and signed by the school principal.

Mertens (2010) stated that researchers should protect the individual privacy of participants and exclude any information that can be identified from the research. In this study, all the participants were informed that all information collected for this research was confidential and would only be used for research purposes. Students' names were pseudonyms to keep the confidentiality of the participants' identities. The name and the location of the school were withheld to prevent the identification of participating teachers and students. All materials and collected data would be kept strictly confidential to the researcher, and the identity of all participants would not be disclosed and presented in any way. Students and teachers participated in the research voluntarily. All participants were not paid or remunerated in this research study. It was explained that all the participants had the right to withdraw from the studies at any time.

3.8 Limitation

It is no doubt that all studies exist limitations and difficulties. Several issues with the current study are recognized and discussed.

The present study is only limited to a small group of students from one secondary school in Hong Kong. It is not generalizable to the entire population large scale statistical analysis (Stake, 2005; Yin, 2006). Yin (2009) also suggested the researcher to conduct at least six cases for generalizing the research outcomes.

Qualitative research including interviews and observations were limited to a group of participants. They were not representative to the educators and students in Hong Kong context. The measures of variables are mostly dependent on individual students' and teachers' perception of their situation. A concerted way was carried out to recruit a larger number of students (N=249) for the questionnaires in the first stage of the research concerning the attitude change of creative thinking in STEAM education.

The setting of observation may have limitation. The participants might feel uncomfortable by having their work scrutinized or raise their level of alertness during class. Participants might change how they act or behave (Bryman, 2004; Cohen et al., 2005; Flick, 2009; Wellington, 2000) and affect the reliability of the investigation. Many scholars (Cohen et al., 2008; Patton, 2002) state that an observer who is physically present in the observation can never be completely neutral and thus intervene the natural behavior of the participants.

Convenient sampling was employed in this study. The participants were taken from a group of students who were easy to match their availability and agree to participate in this research. These selected subjects cannot be considered as the representative of the entire population. This sampling method may lower the external validity.

As said, no studies exist without limitation. The above-mentioned limitations do not affect the contribution of this study. Instead, it paves a pathway to suggest new questions and perspectives for future research.

IV. DATA ANALYSIS AND RESULTS

This chapter organizes and summarizes the data that collected from the questionnaire, observations and interviews.

4.1 Analysis of Questionnaires

4.1.1 Reliability

As shown in Table 4.1, Cronbach's alpha analysis was used to determine the reliability of the close-ended questions of the survey instrument both pre- and post-test. There are 28 questions in total in this questionnaire. 5 questions are set to get the information about the participants' personal background of music learning. 21 questions about the participants' self-evaluation on creative thinking are set in 5-point Likert scales. It is shown that the results were highly consistent across the variables, suggesting excellent reliability for the data collected in this study (**α** = .965) for the 21 items (which are set in in 5-point Likert scales in the survey).

Reliability Statistics	
Cronbach's Alpha	N of Items
.965	21

Table 4.1: Reliability of the Questionnaire

Cronbach's alphas for the components of *Originality* (6 items), *Flexibility* (6 items), *Fluency* (6 items) and *Elaboration for creative thinking* (3 items) were .95, .945, .934 and .929, respectively, which is presented in Table 4.2.

Ideational Behaviour Scale ***adopted with modification from the framework of the creativity measurement from the Runco Ideational Behavior Scale (2001)***	
Originality 1. I have many creative ideas when participating in STEAM-*Makey Makey* activities. 5. I come up with an idea or solution that other people have never thought of. 7. I consider that it is important to be able to think of extraordinary and unique possibilities. 10. I am interested in participating in the STEAM-*Makey Makey* project, which is based on your own ideas. 17. I am able to think up answers to problems that I could not figure out before. 21. I have ideas about new inventions or how to further improve the STEAM-*Makey Makey* project.	
Cronbach's alpha (6 items)	.95
Flexibility 6. I like to play around with ideas for the fun of it. 8. I would rate myself highly at being able to come up with different kinds of ideas. 14. I often find that one of my ideas has further led me to other ideas, and I end up with an idea but I do not know where it comes from. 16. I try to think the STEAM-*Makey Makey* project from different perspectives. 19. I am good at combining ideas in different ways that others have not tried. 20. My groupmates ask me to help them think of ideas and solutions.	
Cronbach's alpha (6 items)	.945
Fluency 2. The number of ideas that I may offer is more than those of the other groupmates. 4. I come up with a lot of ideas for problem solving during the discussion in the STEAM-*Makey Makey* project. 12. Sometimes I feel so interested in a new idea that I forget about other things. 13. When having discussions with groupmates in class, I often have trouble staying with one topic because I think of so many things to express. 15. I may develop a variety of ideas at once. 18. I have always been an active thinker – I have lots of ideas.	
Cronbach's alpha (6 items)	.934
Elaboration for creative thinking 3. I often get excited by my own new ideas in the STEAM-*Makey Makey* project.	

9. I enjoy the freedom to make up my own mind and brainstorm the ideas in the STEAM-*Makey Makey* project.	
11. I am able to concentrate on the newly designed STEAM-*Makey Makey* creation.	
Cronbach's alpha (3 items)	.929

Table 4.2: Items of the creativity measurement and its internal consistency reliability

4.1.2 Descriptive Analysis

The Runco Ideational Behavior Scale (RIBS) was used with modifications from the framework of the attitude towards creativity in the idea creation process from Runco et al. (2001) The original version of Runco Ideational Behavior Scale (RIBS) was attached in the Appendix 1.

The means of 21 items are presented in Table 4.3. All items except 2 items (Q12 &13) in the dimension of *fluency* have a mean score above 3, which are rated in 5-point Likert scales. It indicates that the majority of the respondents agree the statement of each item in all the 4 dimensions of creative thinking after participating the STEAM project in this study. The highest mean (*M*=3.34) is shown in Q7 among the statements, which is still close to 3 (neutral). As such, it indicates that the majority of students in this study feels neutral to perceive themselves to be able to think of extraordinary and unique possibilities in the STEAM project. The lowest mean (*M*=2.89) is shown in Q13 among the statements, that indicates that only few students believed that they have trouble staying with one topic when having discussions with groupmates in class. It shows that *fluency* in creative thinking is placed comparatively lower than other dimensions of creative thinking from students' perspective.

Variables	***Mean***	***S.D***
<u>Originality</u>		
1. I have many creative ideas when participating in STEAM-*Makey Makey* activities.	3.21	.931
5. I come up with an idea or solution that other people have never thought of.	3.06	.871
7. I consider that it is important to be able to think of extraordinary and unique possibilities.	3.34	1.016

10. I am interested in participating in the STEAM-*Makey Makey* project, which is based on your own ideas.	3.25	.993
17. I am able to think up answers to problems that I could not figure out before.	3.15	.843
21. I have ideas about new inventions or how to further improve the STEAM-*Makey Makey* project.	3.27	.978
Flexibility		
6. I like to play around with ideas for the fun of it.	3.27	1.042
8. I would rate myself highly at being able to come up with different kinds of ideas.	3.11	.929
14. I often find that one of my ideas has further led me to other ideas, and I end up with an idea but I do not know where it comes from.	3.07	.985
16. I try to think the STEAM-*Makey Makey* project from different perspectives.	3.24	.937
19. I am good at combining ideas in different ways that others have not tried.	3.16	.973
20. My groupmates ask me to help them think of ideas and solutions	3.24	.927
Fluency		
2. The number of ideas that I may offer is more than those of the other groupmates.	3.11	.912
4. I come up with a lot of ideas for problem solving during the discussion in the STEAM-*Makey Makey* project.	3.20	.973
12. Sometimes I feel so interested in a new idea that I forget about other things.	2.97	.999
13. When having discussions with groupmates in class, I often have trouble staying with one topic because I think of so many things to express.	2.89	1.012
15. I may develop a variety of ideas at once.	3.07	1.025
18. I have always been an active thinker – I have lots of ideas.	3.22	.958
Elaboration for creative thinking		
3. I often get excited by my own new ideas in the STEAM-*Makey Makey* project.	3.13	.989
9. I enjoy the freedom to make up my own mind and brainstorm the ideas in the STEAM-*Makey Makey* project.	3.28	.996
11. I am able to concentrate on the newly designed STEAM-*Makey Makey* creation.	3.26	.995

Table 4.3: Summary of the means in the participants' attitude towards different dimensions of creative thinking (*N=249*)

According to Table 4.4, participants (n=249) stated that attitude change towards elaboration (M=3.22) and originality (M=3.21) in creative thinking is more distinguished after participating the STEAM activities. It means that students are more willing to create and extend unique ideas after participating in the creation of the human-centred design instruments in the STEAM project. The result shows that students' attitude change in fluency after participating the STEAM activities is comparatively low (M=3.09) out of the four dimensions in creative thinking.

Dimensions		Originality (Q1,5,7,10,17,21)	Flexibility (Q6,8,14,16,19,20)	Fluency (Q2,4,12,13,15,18)	Elaboration (Q3,9,11)
N	Valid	249	249	249	249
	Mean	3.21	3.18	3.09	3.22

Table 4.4: Means of attitude change in different dimensions of Creative Thinking after participating the STEAM project

4.1.3 T-test Analysis

Table 4.5 further examines students' levels of self-assessment in attitude towards creativity under different situations in real world settings. Group A (secondary school students create HCDIs for Adult) and Group B (secondary school students create HCDIs for Children and Elderly) showed significant increases from the pre-test to the post-test in the dimensions of *Originality*, *Flexibility*, *Fluency* and *Elaboration*. Among these four dimensions, the highest mean score in *Originality* was found in Group B (M = 19.4), t(158) = 4.764, $p < .001$, d=.17 in the post-test result, with a mean difference of 0.78 within the group, after accounting for the pre-test score (M = 18.62). These data showed that Group B students who designed the HCDIs for Children and Elderly (with more constraints), demonstrated a distinct increase in their level of attitude change towards creative thinking, particularly in the dimension of *Originality*. It suggested that students displayed ideas at a relatively high level of unusualness after participating in the STEAM project through the application of situated knowledge in everyday life.

Dimensions		Pre-test	Post-test	df	t	Sig.	d
Originality (6 items)	Group A (n=90)	17.96 (4.532)	19.09 (4.926)	89	4.571	.000	.24
	Group B (n=159)	18.62 (4.318)	19.40 (4.650)	158	4.764	.000	.17
Flexibility (6 items)	Group A	17.73 (4.522)	18.62 (4.893)	89	4.176	.000	.19

	Group B	18.58 (4.207)	19.35 (4.634)	158	5.281	.000	.16
Fluency (6 items)	Group A	17.18 (4.242)	17.82 (4.228)	89	2.699	.008	.15
	Group B	18.13 (4.411)	18.84 (4.743)	158	4.705	.000	.15
Elaboration for creative thinking (3 items)	Group A	8.88 (2.430)	9.39 (2.871)	89	3.704	.000	.19
	Group B	9.52 (2.415)	9.82 (2.591)	158	3.201	.002	.12
All	Group A	61.74 (14.824)	64.92 (16.145)	89	4.496	.000	.20
	Group B	64.84 (14.619)	67.41 (15.817)	158	5.810	.000	.17

Table 4.5: Paired sample t-test of Group A (Adult) and Group B (Children and Elderly) in different dimensions of creative thinking

In Table 4.6, comparisons were made to examine students' levels of attitude difference regarding creative thinking under different situations in 'real-world context' (Lo, 2019). As such, there were no significant differences between Group A (Adult) and the Group B (Children and Elderly) in most of the dimensions, except for *Elaboration for creative thinking* in pre-test. Here, the independent-samples t-test indicated that the scores were significantly higher for Group B (M= 9.52, SD= 2.415) than for Group A (M= 8.88, SD= 2.430), t(247)= 2.018, p<.05, d= .26.

Dimensions		Group A (n=90)	Group B (n=159)	df	t	Sig.	d
Originality	Pre-test	17.96 (4.532)	18.62 (4.318)	247	-1.140	.256	.15
	Post-test	19.09 (4.926)	19.40 (4.650)	247	-.490	.624	.07
Flexibility	Pre-test	17.73 (4.522)	18.57 (4.207)	247	-1.460	.146	.19
	Post-test	18.62 (4.893)	19.35 (4.634)	247	-1.170	.243	.15
Fluency	Pre-test	17.18 (4.242)	18.13 (4.411)	247	-1.663	.098	.22
	Post-test	17.82 (4.228)	18.84 (4.743)	247	-1.685	.093	.22
Elaboration for creative thinking	Pre-test	8.88 (2.430)	9.52 (2.415)	247	-2.018	.045	.26
	Post-test	9.39 (2.871)	9.82 (2.591)	247	-1.223	.222	.16

All	Pre-test	61.74 (14.824)	64.84 (14.619)	247	-1.595	.112	.21
	Post-test	64.92 (16.145)	67.41 (15.817)	247	-1.183	.238	.16

Table 4.6: Independent sample t-test of Group A (Adult) and Group B (Children and Elderly) in different dimensions of creative thinking

4.1.4 Correlation Analysis

With references to Table 4.7 by using the test of Pearson's product-moment correlation, it is shown about the students' attitude towards the originality of creative thinking when they partcipated in the STEAM project in designing the human-centred design instruments in groups. There is a significant, strong and positive correlation between the level of peer learning and the students' attitude towards the originality of creative thinking (*r=.666, r=.644, n=249, p<.01)*. The correlation suggests that the higher level of peer learning in the STEAM project, the students are more able to think of new inventions and solutions to the problem and make further improvement in their human-centred design instruments.

Correlations

		Q.17(Originality) I am able to think up answers to problems that I cannot figure out before.	Q.21(Originality) I have ideas about new inventions or make further improvement on STEAM -MakeyMakey Project.
Q.20 (Flexibility) (My groupmates ask me to help them think of ideas & solution.)	Pearson Correlation	.666**	.644**
	Sig. (2-tailed)	.000	.000
	N	249	249

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.7. Correlations about the participants' attitude towards originality of creative thinking in peer learning

A Pearson product-moment correlation coefficient was computed to assess the relationship between the problem solving through discussion and the students' attitude towards the originality and flexibility of creative thinking in Table 4.8. There was a positive correlation in the students' attitude between the two variables – *fluency* (Q4) and *flexibility* (Q6) *(r = 0.681, n = 249, p< .01)*, which is statistically significant. It shows that the more ideas that the students think of during the discussion in the STEAM project, the more enjoyable that the students like to play around the ideas. A positive and significant correlation is also suggested in the students' attitude between *fluency* (Q4) and *originality* (Q7) *(r = 0.672, n = 249, p< .01)*, which is statistically significant. It reinforced the relatively strong relationship the students' perception between the level of collaboration and the importance in thinking the uniqueness of the ideas when designing the human-centred design instruments in the STEAM project.

Correlations

		Q.6(Flexibility) I like to play around with ideas for the fun of it.	Q7(Originality) I consider that it is important to be able to think of extraordinary and unique possibilities.
Q.4 (Fluency)	Pearson Correlation	.681**	.672**
(I come up with a lot of ideas to problem solving during the discussion in the STEAM - MakeyMakey project.)	Sig. (2-tailed)		.000
	N	249	249

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.8. Correlations about the participants' attitude towards the flexibility and originality of creative thinking in collaborative problem solving

The correlation between the level of interest and the students' attitude towards the flexibility and elaboration of creative thinking is shown in Table 4.9. There was a positive correlation in the students' attitude between the two variables – *originality* (Q10) and *flexibility* (Q8) *(r = 0.648, n = 249, p< .01)*, which is statistically significant. It shows that the higher level of interest in participating the STEAM project which is based on students' own ideas, the wider variety of ideas the students may come up with in the learning process.

Another distinguished result is the positive and significant correlation between the level of interest in the STEAM project (Q10) and the students' attitude towards elaboration (Q9 and 11) of the creative thinking in the STEAM project *($r = 0.782$, $r = 0.755$, $n = 249$, $p < .01$)*. It reinforces the strong relationship between students' attitude in their originality and elaboration of creative thinking. It shows that when students are interested in the activity that can let them express their own ideas, they are more concentrated and motivated to brainstorm the ideas.

Correlations

		Q.8 (Flexibility) I would rate myself highly in being able to come up with different kinds of ideas.	Q.9 (Elaboration) I enjoy the freedom to make up my own mind and brainstorm the ideas in the STEAM – MakeyMakey project.	Q.11(Elaboration) I am able to concentrate on the newly designed STEAM - MakeyMakey creation.
Q.10 (Originality) (I am interested to participate in the STEAM - MakeyMakey project which is based on your own ideas.)	Pearson Correlation	.648**	.782**	.755**
	Sig. (2-tailed)	.000	.000	.000
	N	249	249	249

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.9. Correlations about the participants' attitude towards the flexibility and elaboration of creative thinking when feeling interested in the project

4.2 Analysis of Interviews – with students

15 students (n =15) attended the focus group interview. These students were divided into 3 groups before the STEAM project started, namely as 1. Kids; 2. Adults; 3. Elderly. They were assigned the tasks in designing the human-centred design instruments for different age group users (i.e. Kids, Adults and Elderly). Each group consisted of five students. These three interviews took place in the classroom separately in three days and they were all scheduled after normal classes. The duration of the interviews ranged from 1 hour to 1 hour 15 mins and they were all audio-recorded.

The interviews were about the sharing about the self-discovery from the participants during the design process, and they were extracted with reference to the concepts generated from the guiding framework of "Creative Learning Spiral" by Mitchel Resnick (2017). These conceptual themes were the five stages of the spiral cycle in the creative process for developing creative thinking skills. They were namely as Imagine, Create, Play, Share, Reflect and back to Imagine. In the interviews, students shared how their creative thinking promoted through experiencing the real world and tackling the actual problem in each of the stage as shown in the Table 4.11.

Self-discovery from students in the design process	
Imagine	• Imagine from personal experience and real-world perspective • Learning across disciplines
Create	• Application of integrated prior knowledge • Diverse use of materials for exploration
Play	• Play the designed product from target users' perspectives • Problem finding and solving when playing the product during site visit
Share	• Peer-to-peer learning through sharing • Collaborative learning for idea generation
Reflect	• Necessary qualities to be student designer • Re-conceptualization of homework: from passive homework completion under didactic teaching to proactive of learning ownership under STEAM learning

Table 4.10: Self-discovery from the participants during the design process that they shared in the interviews

IMAGINE

Imagine from personal experience and real-world perspective

The design activity provided the participants a stimulus to creative thinking through identifying the actual needs of the product user.

> *"(after they interviewed the target users) ...maybe every adult has their own instrument and if we use violin… another teacher will not like it, so we think that listening to music is mainly the most thing adults like."* – Adult group

All the participants had the opportunity to meet the product users and get a deeper understanding about the real needs of the product users. Students who designed the HCDI for kids were invited to observe the young children at the kindergarten.

> *"their (the kids') actual need is some entertainment …because they have a lot of homework and they need some entertainment to feel free and play for a little while to have a rest, so the actual needs are entertainment.* ."– Kids Group

Students who designed the HCDI for adults would talk with their target adults including teachers, parents and relatives. Students who designed the HCDI for elderly were invited to communicate from the elderly from elderly home.

> *"(the human-centred design instrument) really matches their personal experience because the elderly we interviewed, she likes to play the rap, the Chinese one. And then she told us that she likes to play music and she likes to listen to music, but she didn't have chance to experience the zheng."*– Elderly Group

Students in the interview described that their imagination of the product design was linked with personal experience as kids.

> *"Yes (it's related to my personal experience), because this is a cartoon song…and (for kids) I think they love cartoon or movie songs very much and they love*

something which is very colorful and it will be very attractive and they will enjoy it very much."– Kids Group

They also started their imagination from the problems that the users encountered without the product or the intents to improve the quality of life for the target users in real-world context.

Learning across disciplines

It was seen that students were able to imagine their product design with their disciplinary knowledge across different learning domains. Some students reflected that they visualized their mental image of their human-centred design instruments with drawing and mind maps in their own way.

> *"We write mind maps. We write down different ways, different areas and we tried to elaborate our ideas to see, to make the best choice we can."* – Adult group

> *"We tried to use papers and draw our concept out to see which one is the best one… with 2-3 draft…"* – Adult group

Throughout the design process, it was shown that various subject matters and students' personal experience were strengthened cohesively and certain level of transdisciplinary STEAM competencies were developed.

> *"I think they involve all. First technology we have the MakeyMakey and the sketch and the engineer we need to build the whole thing ourselves. For mathematics, when building like measure for example "how long is this?", "how long it should be?", "will be too heavy or will it be too light?" ; and the material, for science like will it crash, if I change a metal thing or aluminium foil will it make a sound; or if I just press is it okay if we just press here but not here. It involves a lot of science."* – Elderly Group

CREATE

Application of integrated prior knowledge

Students expressed that they made good use of the prior knowledge that they enriched before when creating the human-centred design instruments.

> *"I found that actually all the subjects can be combined together and make a product… and (also) I can apply my daily knowledge on making this. I feel really successful."* – Elderly Group

Quite a number of students mentioned their prior knowledge in *Scratch*, which benefits much in their design process.

> *"… Yes (have prior knowledge and apply smoothly) we know a lot about the Scratch knowledge when we are in primary school and we know how to make the custom and also we know how to make the sound and also other effects…"* – Kids Group

The importance of the integrated prior knowledge was seen in students' creative process. It can help students to explore and broaden the possibilities of new ideas. Students' attitude was positive when they were able to connect their prior knowledge in their product design.

Diverse use of materials for exploration

Results in the interviews with students also indicated that students explored wide variety of materials for designing the human-centred design instruments.

> *"We used the foam board and then I got some boxes from the snacks and also the cardboard also the popsicle stick."* – Elderly Group

Most of the materials are popular used in our daily life. It was seen that most students are eager to explore different materials for experiment in order to realize the mental image of their designed products.

> *"…other than aluminum foil, maybe coins. But we still used aluminum foil at last. Because it can have a big surface. Coin is only very small and then we cannot have so much things connected to it." – Adult Group*
>
> *"… I searched this one. This, the cotton, and I think that it is exactly the height of this thing."* – Adult Group

They have high degree of autonomy in the selection of learning materials to support their creative thinking.

> *"…we think of some materials, for example, we think of foam board, we think of cardboard, we think of other things. Finally we choose the best one and we order it like foam board is the first, and then we found that foam board is not working so we change to the second one."* – Elderly Group

Their attitude towards the fluency in creative thinking is quite proactive and they tried to think of numbers of materials to perfect their products.

> *"I think that we can use some harder paper to draw the cartoon characters because it will be broken."* – Kids Group
>
> *"…For the first two to three weeks, I think we are using foam board, (but)…we find that the foam board will break when we stick it. So we change it to cardboard but because the cardboards are not too thick, we find that we need a lot of them like it's a bit waste [ful], so at last we think of using the snack box and then we stick them all together and it will form a very thick cardboard and it's also very strong like recycling. I think it's quite good for using recycle materials…"* – Elderly Group

PLAY

Play the designed product from target users' perspectives

It was observed that students were able to respond well and successfully cater the users' needs when designing the human-centred design instruments for the target groups in the STEAM project. They noticed the characteristics of each target group with empathy and consider their strengths and limitations when using the intended product.

> *"…we pay attention to the space… because when it is too close to each other, maybe the music will combine together and it will be very messy…we also care about the safety because at first we want to make something which is addible to let them to click and be more attractive…but because of the safety we don't want them to eat the product so we decided to make a simple paper to cut the characters."* – Kids Group

They concerned the safety of their newly design product and revamped it to be more user-friendly with the balance of their abilities in creativity and contextual understanding.

> *"…we mainly put the wires inside this box so they (the elderly) won't easily get hurt by the wires and also we covered some of the connection parts so that they won't get hurt easily. And the words are big so they can see easily…"* – Elderly Group

> *"…I may think about the size of the hole. Because we are still child(ren), our hands may be smaller than them [theirs], so maybe we can press (the button) …but the adults can't. So at last we try to make a bigger hole for them so they can press easily."* – Adult Group

Problem finding and solving when playing the product during site visit

All students in the interview expressed that the site visit played a very important role for designing the human-centred design instruments as they were able to witness and identify the problems in person through the conversation with the users.

> "*Yes, (important to have site visit). Because we don't really know that how the users will feel about this….(After the site visit), we can…improve our product…when we make it, we didn't know that how adults think and they may have some misconceptions about how to do, how to play it…"* – Adult Group

> *"…when they try the instrument, they told us these letters are not big enough and we just write it over here first and they tell that they cannot see it clearly... so we*

enlarged it. I think it is something that we should improve like we should think more in the angles of the others..."" – Elderly Group

They valued the iterative process of playing the product with the target groups and felt very encouraging when receiving positive feedbacks from the users.

"…the elderly says a few lines which really inspire me. He tells me that not everyone are (is) willing to help the elderly or make something for elderly, he appreciates … a lot." – Elderly Group

"I think because we really paid a lot of effort and spent a lot of time…I think that despite we spent a lot of time…(and) we have overcame a lot of difficulties, at last we get the appreciation…, they still encourage us… appreciate us and thank us…which is very supportive to me…." – Elderly Group

They engaged in the learning process of understanding different scenarios from different parties and were able to move beyond the specific disciplinary knowledge for problem solving.

SHARE

Peer-to-peer learning through sharing

All participants from the interviews expressed that they benefit a lot in peer-to-peer learning mode in the STEAM project.

"…We learn a lot in this process and we learn to pay more effort and listening to others' point of view and collaborate and this also improves our communication between each other and listens to other feedback." – Kids Group

This STEAM project helps the participants to increase their willingness or openness to share with peers in the discussion.

"…at first I was a bit scared about sharing my ideas and opinions, but our groupmates will encourage me so I will try to share..." – Elderly Group

Moreover, the feedback from peers can help to make fewer mistakes and students tend to respect and accept others' ideas.

> *"…if we do this project individually, we cannot have as much ideas we can, and maybe we can reduce the errors when we do the project together with our peers."* – Adult Group

> *"…When I thought of my idea, I really wanted to use it because I think it is very good and it's the best one. After I have talked with my groupmates, I found that sometimes they may think of something which is better than me [mine]. After learning to accept and respect their ideas, I will learn from them that they can think of some ideas which is better than me [mine]."* – Elderly Group

Collaborative learning for idea generation

It is seen that students have a very positive attitude towards collaborative learning.

> *"…I think it's better with a group work style because we did not have this kind of experience before, so more people can think some better ideas and try to have better concept how to make it. Different people have different strengths, we can gather our strengths together to make the best device we can."* – Adult Group

> *"…It works better because it will be faster when we have teamwork…"* – Kids Group

Students' ability in fluency and elaboration skills in creative thinking were strengthened after participating the STEAM project in groups.

> *"I think I learnt more about in group works because I learn to communicate and because when I knew that when there is (are) four people, we may got more ideas and we can share through communication and how to do better."* – Kids Group

In this teamwork sharing approach, they constantly built on and extended one another's work based on the responsiveness to the suggestions or new ideas from their groupmates.

"…Before we shared our ideas and we just think of our own ways…but after we shared our ideas and thoughts, we find that we can have a best one when we give our ideas and we just combine them and make it better." – Elderly Group

"…One person will only think of one direction. But then if there are four people, other groupmates may think of other directions so we can make use of each other's idea and make a better thing at the end." – Adult Group

"…Yes, sometimes we have different feedbacks so we combine together, we learn to combine together and it will be more… the idea will be more interesting and amusing…" – Kids Group

REFLECTION

Necessary qualities to be student designer

Students in the interview reported their delighted feeling in becoming the student-designer.

"I think it is a memorable experience, because it's the first time that we try to make our product and it's the first time for us to be the designer, not the user." – Adult Group

Most of them were positive towards the creative learning experience in the STEAM project.

"I think creativity is important because I'm not a very creative person but I think this MakeyMakey (project) can help me to be more creative…" – Elderly Group

After participating the STEAM project, the students re-perceived that they have the necessary quality to be the designer and create something new and meaningful to the society.

"I think we need to have the patience because maybe we will fail many times for some of the parts, so we need to be patient to fix it…" – Adult Group

"...At first, we don't know what to do. If we don't have perseverance, we can't find how to activate it and our project will fail." – Adult Group

"…we should have a good communication skills and cooperation skills…. if we have any arguments…we can't make this product out. We need to patient and listen to others' ideas so that we can have a better result." – Adult Group

"Observant. Observe the target groups and their needs for the target group." – Kids Group

Re-conceptualization of homework: from passive homework completion under didactic teaching to proactive of learning ownership under STEAM learning

A number of students expressed that their attitude change towards the hands-on design experience after participating the STEAM project.

"…We think that this (project) is having more fun and we will pay more effort to do it." – Kids Group

"…at first I just treated this project as a homework and my only goal is to finish it. After interviewing the elderly, I think that making this product is a challenge for me to do something for them. So, I started to work hard and paid a lot of effort." – Elderly Group

"… I like this (project) better than the traditional because the traditional maybe some teachers their lesson quite boring and we didn't listen to them well. But this project will let us participate more and we can learn more and have fun." – Kids Group

Most of them had fun in the activity and felt satisfied after they successfully completed the task in making their human-centred design instruments.

"When you pay all your effort to this project and you see the kids are (playing) very… enjoying this project, this is worth(y)…"– Kids Group

Throughout the STEAM project, it helps to broader their engagement and raise motivation in creative thinking.

"Before…we just have homework and we can copy the answer on the book but this project is not like this… it needs your creativity and you need to think more problems…that benefits.." – Kids Group

"…In our daily lessons, mostly we didn't need to use our creativity, but we just try to understand it so we can learn it. But (in)MakeyMakey class, you (we) didn't

only need to understand, you (we) also need to try to use creativity and cooperation skills to make this to express our ideas…" – Adult Group

4.3 Analysis of Interviews – with teacher in-charge

An interview with the teacher in-charge of the STEAM project was arranged after the implementation of the HCDIs design activities. It was a short one which last around 10 minutes. It was reflected that the main difficulty in implementing the STEAM project was lack of knowledge and the absence of the standardized curriculum, but the interviewee believed that the students performed well and were able to match the course expectation. The teacher felt encouraged to witness the students' proactive attitude in improving their product design in order to cater the users' needs. Different situations and challenges in the stage of preparation, teaching and reflection of the STEAM project were mentioned. The responses from the teacher in-charge in the interviews were extracted as follow:

Preparation

> *"The STEAM team found it difficult to learn new things, especially programming. It made us feel so anxious if the teaching content is too abstract…"*
>
> *"It is difficult to adjust the teaching and learning pace for each class as their (students') ability and interests are different. It was challenging to set the learning objectives based on the students' capability…"*

Teaching

> *"Students think lots of diverse ideas and somehow they are easily off-track…We encouraged students to focus on one of their (target users') needs… we recommended students to narrow down which type of adult they are thinking about…like what are the OL (office lady)'s needs?.."*

Reflection

> *"it is unexpected to find that my students observe the difficulties in score reading from the (target) users… and they use other way to design the product in order to present the music."*
>
> *"…can inspire students with the theme when designing the STEAM curriculum. We did not fully utilize the functions of MakeyMakey…"*

4.4 Analysis of Observation

Verbal and observational data were both generated during the school visits in the implementation of the STEAM project. There were 41 Form 1 students in class participating the STEAM project. Throughout the observation period, students were working in groups to brainstorm the ideas for designing their human-centred design instruments. Researcher was a present observer, but in the role of non-participant in the class. It was identified that students in the class, who were good at music and arts, were able to think of more ideas about the product design. They focused more on the appearance of the product. Most of the students were proactive in expressing their opinions and providing feedback. It was observed that this activity allowed some students to demonstrate their individual strengths including skills in technology, drawing and musical instruments. It was identified that some students in the group were more willingly to share and they were well-respected by their groupmates. It was seen that the collaboration was efficiently taken place as the groupmates knew each other well and they were confident to elaborate their creative ideas.

On-site visits were arranged in the introductory stage, exploration stage and experimental stage respectively.

Stages	Students' response in the STEAM project
Introductory stage	Students showed different levels in applying the *Makey Makey*. Kids Group: focused more on the musical structure and sound effects. Elderly Group: focused on the technical connection (eg. the circuit setup and programming).

Exploration stage	Students were asked to design a human-centred instrument for different age cohorts and collaborated on ideas that were generated from the group discussion. Kids Group: created nursery games (eg. sponge ball and airplane jump) and focused more on the appearance of the in order to attract other children to get in touch with it. Elderly Group: created Chinese opera and their focus point was more on the process including music making and application.
Experimental stage	Students gave a human-centred design instruments (HCDI) trial to K2 children at the kindergarten. These K2 children actively participated in the activities and were able to improvise simple tunes through play and movement without any prior knowledge by following the instructions of the F1 students as student-researchers.

Table 4.11: Observations in on-site visits

4.5 Summary

The research design of this study clearly showed the curriculum design and the implication of the STEAM project to illustrate how the human-centred design instruments (HCDIs) were applied, which were organized to respond the research question 1. The questionnaire data provides a glimpse of both students' attitudes change towards creative thinking through designing the human-centred design instruments (HCDIs). The interview and observation data were collected for a deeper understanding about the students' experience in the five stages of creative learning and their self-discovery from students in the STEAM project. These study findings were organized to respond the research question 2 and 3, which are posed at the beginning of the study.

<u>Findings of Research Question 1</u>

1. How can the human-centred design instruments (HCDIs) be applied as a tool in STEAM education?

<u>Stage of HCDIs Application in STEAM Education</u>	**A. Introductory Stage**	1. Delivery of *Makey Makey* 2. Hands-on experience
	B. Exploration Stage	3. Idea generation 4. Idea combination
	C. Experimental Stage	5. Instruments operation 6. Needs of target group

Table 4.12: Stage of HCDIs Application in STEAM Education

The human-centred design instruments (HCDIs) can be applied in 3 stages with 6 steps, as shown in table 4.12. In the introductory stage, the invention kit *Makey Makey* was first delivered to students for hands-on experience of the tool in the STEAM project. Moving on to the exploration stage, teachers guided students to generate ideas with different conductive materials that are able to connect the invention kit *Makey Makey*. The human-centred design instruments (HCDIs) were set up after the combination of ideas from different group members. In the experimental stage, students were able to operate their own HCDIs with the target group in order to learn transforming new knowledge for everyday application with meaning through catering their needs in reality.

<u>Findings of Research Question 2</u>

2. How do students' attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) in STEAM education?

	Students' attitude change towards creative thinking

		Paired sample t-test (before and after the STEAM project)	Independent t-test (under different situations in real-world context*) * HCDIs for adult, children & elderly	Correlation among 4 dimensions
Creative thinking in different dimensions	Originality	Significantly increase* **the most distinct increase out of four dimensions*	No significant differences	Significantly correlated
	Flexibility	Significantly increase	No significant differences	Significantly correlated
	Fluency	Significantly increase	No significant differences	Significantly correlated
	Elaboration	Significantly increase	Statistically higher for students who designed HCDIs for children and elderly group	Significantly correlated

Table 4.13: Students' attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) in STEAM education

Overall speaking, students' level of attitude change towards creative thinking through designing the human-centred design instruments (HCDIs) in STEAM education was increased after participating the STEAM project. Based on the students' level of interest and active involvement in the STEAM project, it was noticed that they could express more own ideas (originality and fluency) about the new invention in group work and were able to combine different kinds of ideas (fluency) through discussion. They were more motivated to generate more advanced ideas (elaboration) for the further improvement of the HDCIs to fulfill the needs of the target groups.

Findings of Research Question 3

3. How do students experience the five stages of creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007) in STEAM education?

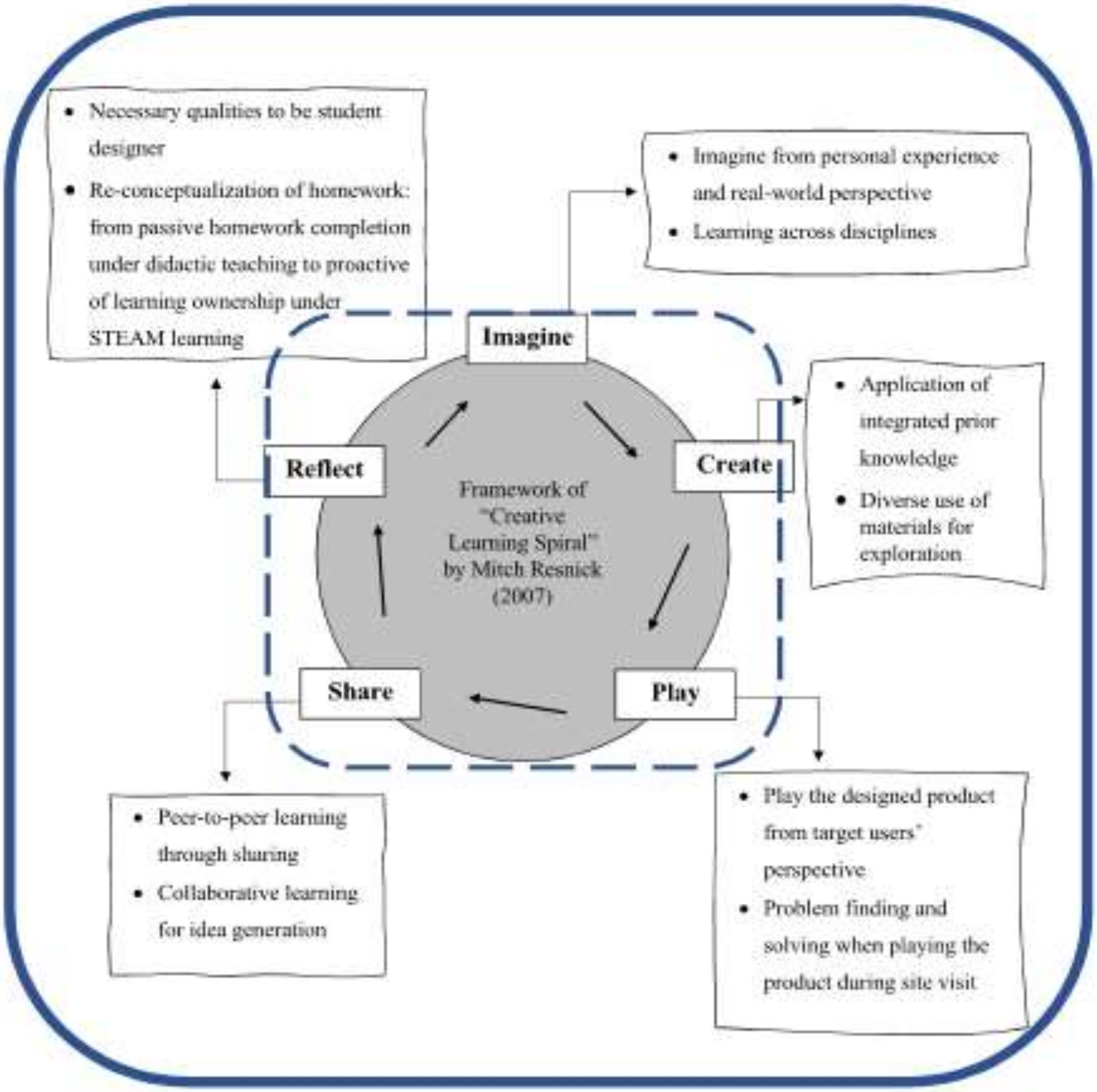


Figure 4.1: Students' experience in the five stage of creative thinking in STEAM Education under the framework of "Creative Learning Spiral" by Mitch Resnick (2007)

The above-mentioned result shown in Figure 4.1 was mainly derived from the interviews with the students, who participated the STEAM project in designing the human-centred design instruments (HCDIs). Thematic analysis was adopted. Codes had been organized in different themes, which were all the students' sharing in experiencing the five stages of creative thinking under the framework of "Creative Learning Spiral" by Mitch Resnick (2007). It was the experience and self-discovery from the participants during the design process in the STEAM project, which fits and provide more in-depth details to illustrate the five stage of the guiding framework of "Creative Learning Spiral" by Mitchel Resnick (2007).

V. DISCUSSION AND CONCLUSIONS

This research concerning the creative thinking and learning in STEAM education is conducted to build evidence about the practice and its effectiveness in order to identify suitable approaches for implementation. This chapter aims to explore the possible research direction for constructing the creative learning-thinking model with the consideration of the availability of tool and the students' attitude throughout the STEAM project in order to guide the in-service teachers the curricular design and conceptualize the teaching and learning practices for STEAM-based activities in the future.

5.1 Creative Learning-thinking Model with 10 guiding principles

With equity as the focus, drawing on wide variety of literature and results from the current data collection from questionnaires in students' perspective, class observation and interviews with both teachers and students, the Creative Learning-thinking Model is developed with 10 guiding principles for the curricular design of STEAM-based activities. The mentioned ten principles are categorized in 5 stages, based on the framework of *Creative Learning Spiral* by Mitch Resnick (2007).

Generic **Stages of Creative Thinking** "Creative Learning Spiral" by Resnick, M. (2007)	**STEAM-Specific** **Stages of Creative Thinking** **"Creative Learning-thinking Model"** **by Lo. J**
	10 Guiding Principles for the Curricular Design in STEAM Education

IMAGINE	1. **<u>Imagination</u>** <u>for Problem Based Learning (IPBL)</u> • Set learning in real world context • Actual needs of product user • Problems encountered in absence of the product • Source of information available for the market needs of the products
	2. **<u>Imagination</u>** <u>with Inter-Disciplinary Knowledge (IIDK)</u> • Visualize the mental image of the product design • Scenarios or any personal experiences for the development of the product • Requirement of certain disciplinary knowledge
CREATE	3. **<u>Creation</u>** <u>with Knowledge Integration (CKI)</u> • Prior STEAM knowledge • Connect prior knowledge to product design • Integration and utilization of both high-tech and low-tech teaching materials
	4. **<u>Creation</u>** <u>with Production Analysis (CPA)</u> • Visualization-by-drawing the product • Freedom in use of materials for designing the product • Adequate time for idea exploration, creation and experiment
PLAY	5. **<u>Playing</u>** <u>from Users' Perspectives (PUP)</u> • Explore characteristics of users' needs with empathy • Interaction with different stakeholders to cater for the users' needs in the product design • Concerns about safety and user-friendliness of the product
	6. **<u>Playing</u>** <u>in the Product Site (PPS)</u> • Figure out the problem in the trial run of the inventions by users • Identification of major gaps between the imaginary scenarios and the on-site trial run • Importance of site visit
SHARE	7. **<u>Sharing</u>** <u>from Designers' Perspectives (SDP)</u> • Teamwork sharing approach with peers • Constructive and diversified feedback (more than one "correct and the best" answer) • Value the "failure" and engagement in inquiry-based discussion

	8. **<u>Sharing</u>** <u>for Product Perfection (SPP)</u> • The responsiveness to the suggestions from the users and open-ended questions from mentors • Problem-solving and modification of the product for improvement • Try out new or extended ideas with peers
REFLECTION	9. **<u>Reflection</u>** <u>from Re-Perception as designer (RRP)</u> • Necessary qualities of a designer motivate creative thinking • Progressive learner in needed basis • Passionate to ask questions for more innovative ideas
	10. **<u>Reflection</u>** <u>as Re-Conceptualization of one's creative thinking (RRC)</u> • Look back the earlier stage of work • Discuss and reflect the design process and thinking process • Cultivate an innovative and supportive environment which shows students' creative ideas are highly valued • work collaboratively and gain hands-on experience to raise motivation and engagement

Table 5.1: Creative Learning-thinking Model in 10 principles

Stage 1: IMAGINE

Principle 1*: *Imagination for Problem Based Learning

Human creativity practically requires unique imagination to work out. It is shown that these two elements are interrelated. Imagination symbolizes subjective life experience, that leads us human (Saunders, 2012) to express a point of view and creates a new idea, which is considered as human creativity (Griffiths, 2014). Educators are highly encouraged to connect the teaching topics to be relevant to the real world. It is much easier for learners to picture their roles in the society first and then able to recognize the need or problem from the society. As such, educators should set different scenarios for students to imagine several roles of participation in the society and their learning can be enriched through combining their knowledge and skills to solve the problem and match the actual needs from all walks of life.

Self-directed learning approach can be applied for the information searching for the needs of the target groups or the related products when implementing at the beginning stage of STEAM project. Resnick (2017) realizes that there is a close relationship between imagination and creativity. He points that human creativity is rooted from an individual's power of imagination and it is a step beyond imagination. Gaut and Livingston (2003) also agree that there is a very strong connection in between the stage of "Imagine" and "Create". "Imagination" was interpreted as the ability to engage in creative thought. Therefore, STEAM teachers should avoid teaching through direct instruction. Educators could inspire students to access wide range of information sources that are available for the market needs of the product. A collection of information that the students find by themselves are normally based on their interests and abilities. Less rote learning can help students to stimulate imagination and formulate more ideas. For beginners, students may design their product based on their preferences or favorites in STEAM projects by taking references on the current ideas. Moving on to the advanced level, students may extend or modify their ideas with the considerations from users into a meaningful and creative product. The process of imagination encourages learners to be active thinkers freely and thus helps to promote creative thinking.

Principle 2: Imagination with Inter-Disciplinary Knowledge (IIDK)

Both imagination and knowledge are in an important position in education. Imagination brings human different mental images in mind (Agnati, L. F.,et.al., 2013) and knowledge helps to support these mental images through the embeddedness of skills and personal experience. The process of imagination supports knowledge acquisition.

The complex problems that are raised by scientific thinkers require creative thinkers, who work on beyond disciplines. Many studies support that curriculum design in interdisciplinary approach is easier to acquire knowledge with connection between concepts and ideas and proved that it can be remembered for a longer period of time (Kovalik & Olsen, 1998). Kovalik & Olsen (2002) states that the chances of long-term memory learning are higher when more areas of brain are involved. Barrett (2005) stated that the intersection between disciplines might lead to a more meaningful and deep understanding.

In STEAM education, students are encouraged to design or create the products for a given scenarios, which requires them to imagine and explore the problem in multiple disciplines. The students feel easier and raise the sense of belongings for students to imagine the multiple solutions to the problems that are encountered in daily life. Intuition, experience and imagination are considered as crucial elements to create possibilities (Woolery, 2006) and encourage them to think as an inventor and designer of the product, regardless of any obstacles to creativity. It is important for educators to take the leading role in guiding students to connect the disciplinary knowledge and build up the synthesis skills in different perspectives with coherent learning experience. All the imagery in mind from different perspectives can be visualize through any forms including concept maps, sketching, simple models or metaphor in order to prepare them for further creative ideas.

Stage 2: CREATE

Principle 3: Creation with Knowledge Integration (CKI)

It is recommended that teachers should take risk and try new lesson plans in class. The direction of the STEAM curriculum should be balanced and broad with the connections between subjects. STEAM education moves beyond disciplines and create new knowledge (Bush and Cook, 2019). It moves towards multiple viewpoints and modes of inquiry (Connor et al., 2015). Ideas are newly created by merging different subject knowledge and solve the authentic problem in real world context with the incorporation of Arts. This type of thinking model moves from interdisciplinary to transdisciplinary. It is very important that educators should strike a nuanced balance between the depth and breadth of the knowledge. It is crucial to include time for students to explore the possibilities through connecting the prior knowledge in the STEAM project. Both teachers and students were not experts in specialized areas, but it is important for both parties to apply the prior knowledge for clarifying and re-defining the problems in new perspectives with a range of various strategies through discussion, instead of only teaching and learning the area in a separate entity.

In order to stimulate creativity, designing tools and material selections are essential from a conceptual process to a practical process (Resnick, 2017). Over the generations, many educators (Dewey, 1938; Kolb, 1984) have advocated *learning by doing*, and then followed by similar approaches including problem-based learning or experiential learning. It is important for students to learn actively with curiosity through hands-on experimentation. It is crucial for student to design and create something new though using interactive and interesting teaching materials and tools, but not only limited in doing something. It is observed that children spend more than 7 hours a day in average on digital media and electronic devices such as smartphones and computers (Strasburger, 2012).

Integration and utilization of both high-tech and low-tech learning tools is highly encouraged to promote creative thinking in STEAM education. It is not surprising that most teenagers nowadays feel motivated and interested in technologies, media, arts and music (Ito, Baumer, Bittanti, Cody, Stephenso, 2009). All these elements play a dominant role in all parts of culture and economy. Use of technology offers students a new way to engage in creative learning and helps to expand the types of project that can be implemented in school setting. It is reflected from the class observation and students' interviews about the design of the human-centred design instruments in the STEAM project. For example, coding in the computer programme *Scratch* leads to the production of animation, sound projects or games. It is suggested to infuse technology in STEAM education to support students' learning. For those teachers and students who are not very experienced in technology may start the STEAM project with simple coding or searching information online while the experienced teachers with STEAM knowledge may lead students to do projects and construct new ideas in more complex level with knowledge integration such as science and mathematics with their own design through the use of technology.

On the other hand, low-tech materials are comparatively accessible in classroom setting. Most of the teachers and students feel so familiarized with these materials in daily life. Diverse materials can inspire students to a concrete direction of their ideas for what they want to create and experiment.

With this utilization of both high-tech and low-tech teaching and learning materials, educators are able to inspire students to treat themselves who can make and create with knowledge integration.

Principle 4: Creation with Production Analysis (CPA)

Artistic and design-based approaches are encouraged to adopt in the STEAM education as the learning outcomes are varied in arts subjects. It is proved that visualize the product in detail by drawing helps students to think more in-depth what they are learning and further build new connections between topics. Park and Brannon (2013) noticed that visual and spatial representations help students to improve the performance in mathematics. Mayer (2008) also states that students learn more effectively from the resources which consist of words and pictures, in comparison to those with words only. Creativity is promoted when students make their decision to draw different images.

Mind map is highly recommended to adopt as a learning tool to implement the STEAM project. Drawing mind map by using keywords, colors, images and numbers is a powerful way for nurturing creative and critical thinking (Cambridge, 2015). It helps learners to identify the relevant concepts and express their views simultaneously. It fully aligns the findings from this study as students in the interviews also reflect that groupmates use mind maps to raise and elaborate their ideas in different ways and try to make the best choice through voting and discussion. Students take a more active role in this learning process and allow them to explore in new perspective and create more brand-new ideas.

Decision-making freedom is one of the prerequisites for creativity (Skulimowski, 2011). Freedom of choice in product creation is associated with the level of creative thinking. From the finding, it is observed that students feel more enjoyable and motivated to decide what to do and how to do when designing the human-centred design instruments in the STEAM project through the way of self-directed learning. It helps to bring more passion to students in engaging the meaningful design experience.

It is crucial to maximize the time for activities which can foster creative thinking in designing the school curriculum. Students should be given adequate time to repeatedly exercise their divergent kills in different situations for idea exploration, creation and experiments. However, the curriculum in Hong Kong is very packed and there is no official rule to promote creative thinking. To be more practical, the teaching strategy in the classroom may guide students to identify the prior knowledge in the context problems. Teachers may then set task constraints and appropriate learning objectives to help students know what they want to learn about the subject. It leads students to have a more concrete direction to "think about their thinking" in the limited time.

Stage 3: PLAY

Principle 5: Playing from Users' Perspectives (PUP)

Play acts as a very important role to extend the range of possibilities in thinking (Csikszentmihalyi, 2002). The STEAM curriculum should include the direction in inspiring students to start with trivial ideas and play around in simple ways. Students may explore from any means of virtual, physical or verbal in an unstructured way and then combine the fragment of knowledge to bring insights to their own designs. Educators can arrange students to engage in different environments as on-site observations to learn more about the actual needs of the users before the STEAM projects. The students who participated the STEAM project in this study obviously shows that the interaction with different stakeholders including users, professionals and even some business leaders may benefit the students to build up their identity as designers and capable of applying different domains of knowledge to create the transdisciplinary designs.

Educators may inspire students to learn in defining the problem with empathy and train their ability in thinking from the position of users. Necessity is the strong drive leading to innovation (Roterberg, 2018). As such, they can prioritize the actual needs of users in certain extent through repeated experiments and continuous feedback. The designed products can be much more aligned with the users.

The hands-on experience with mistakes is a learning opportunity to guide students from a failure to success, which is the integral part of creative process. It is all acceptable for students to make "sensible mistakes" in the ideation process. The extension or improvisation of ideas from old plans with appropriate selection may help to turn the initial thoughts from sketches to tangible products. It aligns with the design thinking approach, which is a comprehensive way of thinking for people in a situation through understanding, observation, defining problems, ideation, developing prototype and testing (Plattner et al. 2009; Roterberg, 2018), that takes place in the stage of play that suggested from Creative Learning Spiral by Resnick (2017).

Principle 6: Playing in the Product Site (PPS)

Play is an essential element in learning. Resnick (2018) raised a question about "edutainment". It is a term with the combination of "education" and "entertainment". He stated that learners should be moving on to the active role to "play" and "learn" with all hands-on materials and situated environment, rather than keeping the passive role in waiting for different stakeholders to provide materials for their learning.

Arrange project to work out in the product site is a remarkable learning experience for students. From the findings of this study, students shared that they enjoyed the process of site visit in the STEAM project. Students feel excited as they can explain and share their own design in person to the users. They can immediately response to the users' feedback and communicate their viewpoints for making further improvement of the human-centred design instruments. It is in expectation that the actual users' needs is a bit different from what students have thought. It is a way to train students problem solving skills and strike a balance between their creative thinking and the underlying constraints in real world setting through the identification of major gaps between the imaginary scenarios and the on-site trial run.

STEAM curricular is recommended to set learning outside classroom for students to experience real situations. This simple participation brings students a precious opportunity and platform to learn from the theoretic concepts that are taught by teachers at school towards the practical experience in the real-world context that are outside the comfort zone. It is challenging yet students have a strong sense of satisfaction when they overcome a lot of difficulties when designing the human-centred instruments for the target groups. Students found their learning experiences more meaningful and rewarding when they could truly cater the needs from the target group. This interdisciplinary and transdisciplinary learning experience obviously mimics the real-world learning, which aligns the view from Wurdinger (2005) and it showed that experiential learning approach can be considered to apply in the curriculum design of STEAM education.

Stage 4: SHARE

Principle 7: Sharing from Designers' Perspectives (SDP)

Collaboration is more highly valued than competition (Burke, 2007). Educators are encouraged to inspire students to develop capability to work in groups as collaboration provides students opportunities to develop expertise. It is proved from the findings of the interviews reflected by students who participated the STEAM project. They mentioned that they are able to locate the contribution from each group member and recognize each of their expertise is a crucial factor for the success of their group work. As such, they appreciate each other and thereby create a supportive environment for further discussion or problem solving in their product design. They all agreed that they were able to make related changes for further improvement in the product design in response to the ideas or strategies from other groupmates. The sharing in the discussion raise students' openness and willingness to collaborate with groupmates. It aligns with the view from Totten (1991) that collaboration helps students to take responsibility in their learning and think critically.

It is crucial to train students thinking in diverse perspectives and there is always more than one possible solution before reaching to the best answer. The finding shows that secondary students are able to express diversified feedback and state their preferences. Students value their gain of knowledge from the peers and are eager to try out different ideas even though they face obstacles or failure in the process. Educators should guide the students to value the failure and spark the improved ideas in inquiry-based discussion.

The peer interaction acts as a motivational scaffolding (Lee, 2003). Learning in groups enables students to make decision and self-determine the level of their individual involvement as well as the degree of contribution in the thinking process. The teamwork in the STEAM project does not aim to work together physically, but students are required to have the common goal to solve the problem through sharing their ideas, that one individual may learn the needs of the users and expectation from different perspectives, based on their own personal experiences.

Principle 8: Sharing for Product Perfection (SPP)

Conversation was one of the sources of collaborative creativity (Dunbar, 1997). Learning takes place through the responsiveness to the feedback and suggestions from different stakeholders and promotes critical thinking. The comments from peers, including the pride and encouragement in the collaborative work is considered as important in the group creative process (Aragon & Williams, 2011). Teachers are also encouraged to apply reflective open-ended questions that may have multiple answers as classroom practice in their teaching. The culture of his student-centred learning atmosphere is supportive for learners to generate more ideas and inspire them to work out variety of solutions. It enables the students to develop the curiosity and openness to new knowledge through increasing engagement in problem solving when their contribution in solving the problem is unique and valued. Rowe (1986) stated types of questions and its way of delivery in class can improve the quality of learners' thinking and response. It involves mental processing that can promote creative thinking. Wide variety of questions can be are efficient to probe students to explore the questions further when working in groups through discussion (Kazemi, 1998).

The Creative Learning Spiral concept (Resnick, 2017) sets the stage of share through discussion, which is considered as an essential part of the creative process. Unfortunately, educators often focused on the product design or ideas, and overlooked the process of critical thinking. It is important to provide students opportunities to review the different stages of the working process. Participatory culture starts to be popular in this 21st century (Jenkins, 2006). The students from the interviews in this study recounted that their expectations to the behavior and needs of the user of the human-centred design instruments are different from the actual needs. They reflected that the trial run of the human-centred design instruments can help to picture the scenario and locate the problems accurately. They can revise or fine-tune the initial design for further improvement with group memebrs. Students modify and extend other's ideas through sharing, leading them to the openness and evolvement of their own knowledge foundations (Resnick, 2007; Brandon & All, 2010). It is beneficial for students to maximize the level of knowledge building and foster their self-expression. It matched with the concept of "integrative collaboration" suggested by John-Steiner, which highlighted the shared vision and innovation that were built within the group (Steiner, 2000). It establishes the sense of responsibilities and brings the culture of sharing new ideas or skills with others. This collaborative learning helps to utilize divergent thinking to expand the possibilities or extend the ideas as each individual in the group may have different strengths to contribute a solution.

Stage 5: REFLECT

Principle 9: Reflection from Re-Perception as designer (RRP)

The creative learning process is clearly seen from being a user, and then to be a learner, further to the role of designer. It is important for students to learn the new knowledge that they care about and it encourages students to learn progressively in needed basis. It symbolizes that they build the passion about their work. Educators are recommended to connect students' thoughts and their interests in order to stimulate their motivation during the learning process. The learning attitude changes from the understanding of the theoretic knowledge strictly to the application of the practical knowledge creatively in order to align the needs in the society. Young people nowadays are required to get ready for confrontation and deal with uncertainty in lifetime in order to match the evolving society, so as to develop new possibilities for individuals and communities (Resnick, 2017).

The STEAM project was more than including the knowledge of science, technology, engineering, arts and mathematics. It also provides students a creative learning experience with the process of create, learn and share with others of all ages (kids, adults and elderly), which are totally beyond the traditions. Students are able to input and experience the ideas in the academic practice with the peers and mentors. This creative learning process in designing the human-centred design instruments is powerful as it is not only about learning the concepts of a domain. It is about the students' willingness in engaging a question with the established knowledge to formulate their own perception and understanding to an inquiry. Students are learning to be learners-cum-designers. It aligns with the view of Sternberg (2012) that creativity shows the balance between knowledge itself and the individual's openness to that knowledge. From this STEAM project, students were free to design the human-centred instruments for the specific target groups. The "Arts" element in this project stimulates learner autonomy - a capacity of ability and attitude in the learning process. Due to the perceived high level of freedom and flexibility, the intrinsic motivation levels up when students work on the project they design by themselves, in line with their interests and passion. It is crucial for teachers and parents to help children develop creativity through providing them autonomy (Hellen, 1999).

It is very essential for educators to encourage students to raise their own questions in the STEAM education. It can help learners to recognize the problems in various dimensions and simultaneously consolidate the understanding of the problems (Cambridge, 2015). It is seen that there is a change of attitude from the students in this study, who have designed the human-centred instruments for different targets in the society. Most students are more confident in self-expression and they are eager to get more feedback from different involved parties to perfect their product design through raising questions. Continuous questions may fine tune or even light up the current thinking for more innovative ideas.

Principle 10: Reflection as Re-Conceptualization of one's creative thinking (RRC)

Classroom activities with the lens on different subject matters in real world context motivates teaching and learning. All students in this study who were responsible for designing the human-centred design instruments for three groups of users (kids, adults and elderly) felt more motivated and believed their self-efficacy as creative designers. Findings from the students' interviews reveals that there is an obvious attitude change towards creation, collaboration and communication before and after participating the STEAM project. Students learn to pay more effort in listening others' point of view. Students are more eager to communicate as they can get more ideas from peers for further improvement.

Participating in group designed-based activities may help students to raise their self-confidence, when they feel their designs or creative ideas are unique and valued. Broader engagement is shown where students are valued for their contribution (Olitsky et al., 2010). This supportive environment provides students a platform to show their own authority and they have ownership in their learning. Students may extend their learning interest from passive learners to active researchers and raise the level of self-initiation in learning. The hands-on learning experience project is proved to breed and re-conceptualize creative thinking in STEAM education.

Engagement in inquiry-based discussion in STEAM education explicitly shift students' learning mode from teacher-directed approach to student-centred approach. From the data collected of this study, most students prefer learning from hands-on design experience rather than the traditional way of learning through lecturing or listening. Metacognition strategies are encouraged to apply for students to construct and transfer what they have learnt across domains. Educators should treat reflection is a crucial part during the plan-monitor-evaluate process to identify what students learnt in order to achieve the learning goals efficiently.

Revisiting of the Creative Learning-thinking Model

Based on the data and the principles derived from the above, it is found that the traditional MIT's Creative Learning Spiral (2007) does not sufficient to be applied into the context of STEAM education. This is because the Spiral model is a Generic description of Creative Learning-thinking Process, and it does not illustrate the specific principles and details which happen within each stage of the Spiral if applying into the STEAM context.

In this connection, this research build on the existing Generic Spiral model and further explains the complexity happened within each stage of the Spiral in the application of the STEAM context (RQ 3). The newly developed model opens up the pandora box and necessary must-knows of applying the Generic Spiral model into the STEAM context. Taking an analogy, the significance of this study is to modify the Generic Spiral model into a STEAM-specific Creative Learning-thinking Model with the consideration of the availability of tool (RQ 1) and the students' attitude (RQ 2) throughout the STEAM project. This STEAM-specific Creative Learning-thinking Model advances the development of the General-Spiral in 5 domains as detailed below in Figure 5.1.

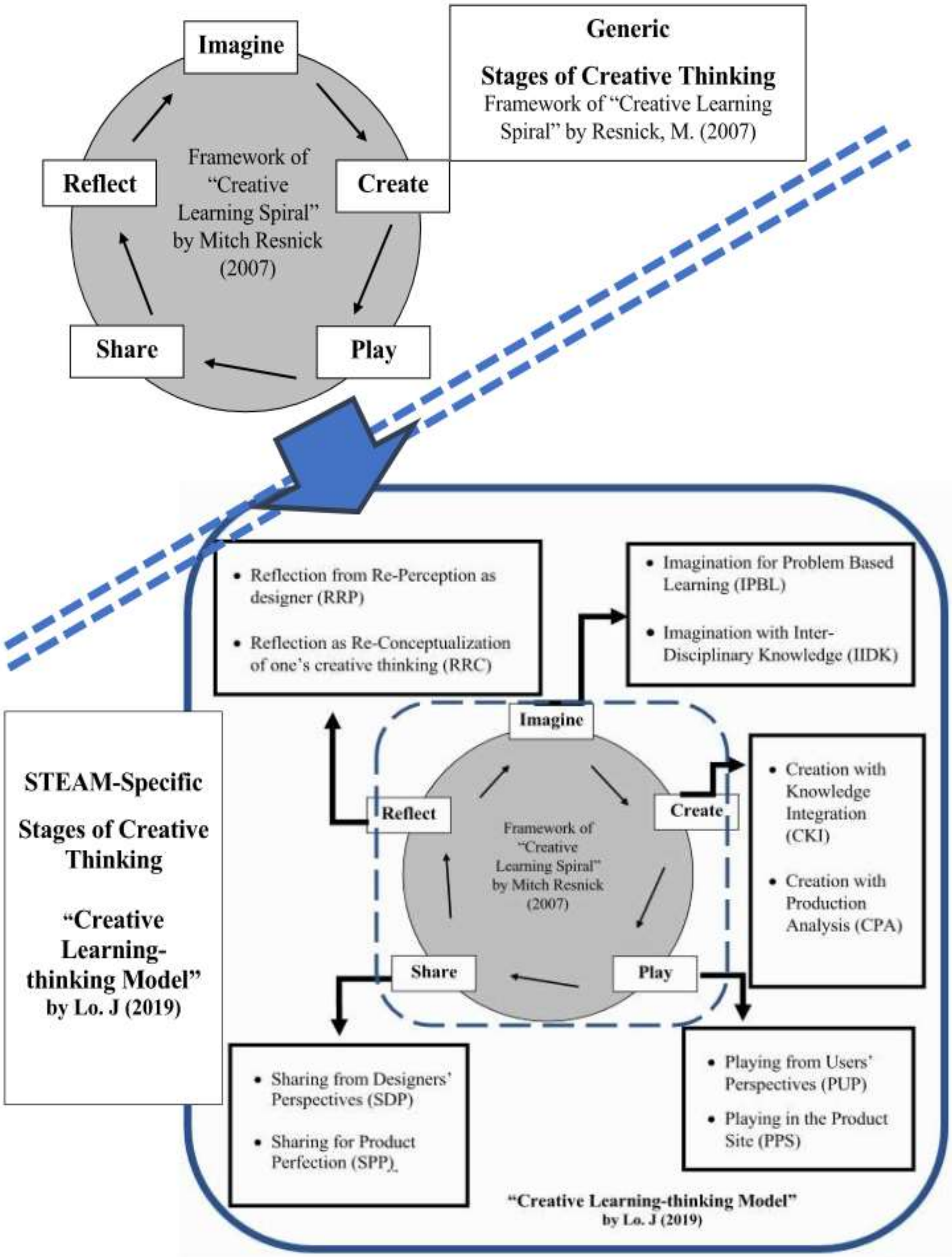


Figure 5.1: Overview of the Creative Learning-thinking Model

5.2 The Implementation of STEAM Education in Hong Kong

It is understandable that it is challenging to implement STEAM Education in Hong Kong. In the research conducted by Geng, Jong & Chai (2019), only 5.5% Hong Kong teachers were considered themselves as well-prepared for teaching STEAM-related curriculum. They mainly had concerns about the pedagogical support, teacher training development, funding and resources during the implementation. In Hong Kong context, it is a lack of guidelines and teaching materials for teaching and learning as there is no fixed or recommended curriculum for STEAM education from Education Bureau.

The Hong Kong Education Bureau (EDB, 2015) came up with six final recommendations for the promotion of STEM education in the report on Promotion of STEM Education, which was released in 2015. No further reports about STEAM Education were published or revised. As a result, many schools are not eager to take one step forward to this transdisciplinary learning and still prefer to use the existing teaching materials and practice, that remains oriented around the traditional models. Most of the teachers are losing their autonomy and create a logic of standardization (Schmidt, 2011).

The quality of STEAM curricula also depends immensely on the education policy and teachers' knowledge, belief and attitude, as mentioned from the literature review in Chapter 2. Given the background of the educational style in Hong Kong, the timetable of many schools is so tight for different key learning areas such as language, mathematics, science and liberal studies (EDB, 2017) that most secondary students are just trying to survive in the exam-oriented education. It is challenging to implement a STEAM curriculum due to the traditions of rote-learning style utilized by teachers and experienced by students. Many educators consider arts education as a far less important learning area than those traditional academic subjects. Expressive art subjects such as music and visual arts are only considered as a tool to teach other subjects in an interesting way.

In response to the teachers' knowledge, many teachers are not equipped with STEAM related knowledge, pedagogy and technology. It is advised to provide professional school-based support and try to shift teacher from curriculum users to curriculum leaders (Choi, 2010) and stimulate the educators to create a shared vision on students' benefit as the ultimate goal.

Belief for teachers is one of the attributes that is very hard to get changed. The leadership structure of an organization or a school plays an important role in promoting creativity and innovation (Agbor, 2008). Teacher-leadership may be applied because teacher participation is crucial to create a sense of belonging and autonomy (Treslan, 2006). Leaders or senior management can act as a catalyst to drive and control the sustainable change in school culture and structure in order to encourage innovative developments.

For attitude, teachers are used to recognize creative arts as a special set of personal skills and not confident in their teaching. In tradition, music knowledge is different from other general subjects and it has been recognized as a special set of personal skills (Neway, 1983). They are not motivated to link music concepts to other disciplines. Professional collaboration across disciplines is not easy. For long-term development, it encourages to focus more on leader-follower interaction. Principals may take initiative to understand the needs of the teachers and promote knowledge transfer. Bottom-up management can be a tactic for more innovative directions in school setting and avoid teachers to work routinely like machines. More teachers with their own area of expertise could be involved in designing the STEAM curriculum as frontline teachers may understand more about the needs and learning process of the certain grades of students. Diversity is one of the core elements for an organization's ability to innovate (Agbor, 2008). The various ideas and talents from different teachers pave a path for the success of promoting creativity and innovation in school setting, rather than only being a pure follower to work on new projects suggested by principals. The level of motivation and sense of belongings will increase as the teachers are also the users of the STEAM curriculum. It may also lead to a positive change of teachers' attitude towards implementation of STEAM education.

5.3 Recommendations

It is important for our young generation to develop creative thinking skills if the society is planned to move forward in taking account of the sustainable development for a better quality of life. Creative thinking skills that are developed in STEAM-based activities may raise our competitiveness and sense of belongings to make informed decision on both personal and public issues, taking the leading roles to improve the world through extending our ability to construct innovative invention.

5.3.1 Strategy for implementing STEAM Education in Hong Kong

❖ *Promote and sustain young learners in public engagement*

Community engagement is a crucial element in building authentic STEAM experiences. With the connection from the literature review, research from Knox, Moynihan and Markowitz (2003) and Ewing (2010) stated that there was a positive relationship between the involvement in STEAM and students' achievement. These scholars found that high school students (grade 6-12) performed better in their studies and felt more interested in the disciplines through hands-on experience in site visits, which they learnt in the way that were not existed at schools, as traditionally perceived. The finding aligns with the view from the questionnaires, interviewers and class observation that were conducted in this research. Participants in this research also showed the active involvement and enjoyment during site visits. They feel excited in sharing and explaining their design of the human-centred design instruments with integrated knowledge across disciplines to the users. Students who have invented the human-centred design instruments for kids, adults and elderly, demonstrates their ability and interests after having the trial with the target groups at kindergarten, their own home and elderly home. Students' on-site participation is influential to the perception of their engagement in STEAM education and also provides students a strong impetus in the form of inquiry-based learning, rather than only leisure and entertainment.

Policy makers or top management from schools are recommended to set the principles of STEAM curriculum design in relevance to the real world, which can help students to build a stronger connection between education and work in the future. Real-life work experiences which provide students opportunities to apply both theoretic knowledge and practical skills is worthwhile to implement in secondary schools in Hong Kong. It helps students to build a foundation knowledge of necessary skills and attributes in the workforce. It also empowers them to locate the personal interests and unique strength. Students may have an early exposure of the career path and map their educational goals to possible futures. School-community collaboration and mentorship scheme could be implemented to explore further possibilities to promote STEAM education and careers. School teachers may partner with community experts to support the transdisciplinary nature in STEAM teaching. In Hong Kong, a remarkable project in 2019 by China Mobile Hong Kong, which involved educational community to launch the World's First 5G STEM Pilot School Initiative, is one of the innovative examples to promote creative thinking in transdisciplinary learning. It allows students to fully unleash their creativity in the unlimited possibilities in 5G development, and also provides teachers a multi-faceted direction for education in the real world setting.

❖ *Roles of teachers in STEAM education*

The role of STEAM teachers acts as a curriculum designer and the role of students in STEAM education act as a researcher in the teaching and learning of STEAM classroom. The direction of the approach is to move from the traditional 'knowledge-based' learning mode to the ‘research-based’ pedagogies. Educators transformed the identity from a content deliverer to a content guide. Teachers may firstly give introduction or deliver a briefing about the STEAM project and students learn through the authentic hands-on STEAM activities directly. It is influential to the perception of students’ engagement in STEAM-based activities and also provides students a strong impetus in the form of inquiry-based learning, rather than only leisure and entertainment.

The Education Bureau has to take the responsibility to play an active role in improving the STEAM instruction by launching partnerships among schools, universities and stakeholders in community. School teachers may connect and collaborate with innovation networks with updated local and international STEAM resources and ensure the utilization, in order to expand the learning platform and transform the teaching and learning.

❖ *Infuse STEAM education in school curriculum*

Currently, STEAM education is only mainly dominated outside school in Hong Kong and China. There is still not a standardized curriculum guide for STEAM education. Only the “Direction of ongoing curriculum development in STEM education” and similar concepts such as “Project Learning: Towards Integrating and Applying Knowledge and Skills across Disciplines” were mentioned in the Secondary Education Curriculum Guide (2017) by the Education Bureau in HKSAR. Linked with the relevant literature, it is recommended that STEAM education should be implemented in the classroom setting with reference to the set of 10 guiding principles that suggested in this study. The tasks could be in the kind of group projects or case studies. The criteria of these tasks should be included the following:

i) start with a problem in real world context that motivates students to solve it

ii) explore the problem with knowledge integration across disciplines (STEAM)

iii) obtain hands-on experience in the experiment of the product design

iv) work on creative ideas collaboratively with communication

v) reflect and evaluate of project outcome

❖ *Assessment rubrics for STEAM education*

STEAM education is conceptualized as transdisciplinary learning, which is problem oriented (Wickson et al., 2006). It is understandable that there are not many experienced STEAM teachers in Hong Kong. As such, there is a lack of systematic ways to evaluate students' performance in STEAM education activities. To avoid the traditional exam-oriented assessment method, a set of assessment rubrics is suggested to identify and evaluate the multiple dimension of skills that are able to be promoted in the STEAM activities. This set of assessment rubrics is mainly divided into five main dimensions with alignment of the five stages from framework of *Creative Learning Spiral* by Mitchell Resnick (2017), which are *imagine, create, play, share and reflect*. These dimensions are also aligned with the elements of creative thinking from different scholars that the literature has been shown.

Dimensions of Creative Learning in the assessment of STEAM Project	Stage of *Creative Learning Spiral* ***Adopted the framework by Mitchel Resnick (2017)***	Elements of creative thinking from different scholars
1) Understanding of Contextual Knowledge	Imagine	Imagination *(Dimitra & Douglas, 2015)* *(Vygotsky, 2004)* *(Higgins, 2008)*
2) Creativity & Innovation	Create	Originality *(Guildford, 1967)* *(Torrance, 1979)* *(Hickey & Webster, 2001)* *(Haroutounian, 2002)* *(Vygotsky, 2004)* *(Runco,2007)* *(Wright, 2010)* *(Dimitra & Douglas, 2015)*

3) Analysis & Interpretation	Play	Fluency *(Guildford, 1967)* *(Clark and Mirels, 1970)* *(Torrance, 1979)* *(Vold, 1986)* *(Haroutounian, 2002)* *(Vygotsky, 2004)* *(Wright, 2010)* *(Dimitra & Douglas, 2015)*
4) Collaboration & Communication	Share	Flexibility *(Guildford, 1967)* *(Torrance, 1979)* *(Sternberg & Lubart, 1999)* *(Wright, 2010)*
5) Critique & Revision	Reflect	Elaboration *(Guildford, 1967)* *(Torrance, 1979)* *(Wright, 2010)*

Table 5.2: The Alignment of Creative Learning Spiral framework and creative thinking elements in the assessment of STEAM project

The detailed version of the assessment rubrics is shown as below. Each dimension can be individually rate on the scale ranging from excellent (A), good (B), satisfactory(C), pass (D) and Fail (F). The criteria and description of level of performance quality in each dimension is clearly stated. It is encouraged to match students' performance to the description in each level, rather than judging the students do it right or wrong. The design of rubrics shows the indicators to access the intended learning outcomes. It is advised to share the rubrics with students at the beginning of the project and let them have a better picture of what they need to achieve during the creative learning process, rather than only focus on the product. It also helps students to move on to the next step in order to raise quality of their performance as all indicators and descriptions are clearly shown. It is also an advantage for STEAM educators to apply this set of rubrics for the STEAM activities. Repeated use of this set of general rubrics on different tasks helps teachers to focus on students' essential skills in each dimension instead of the completion of task.

Table 5.3 Assessment rubrics for STEAM activities					
	Excellent (A)	**Good (B)**	**Satisfactory (C)**	**Marginal Pass (D)**	**Fail (F)**
IMAGINE **Understanding of Contextual Knowledge**	• Deep understanding of the problems encountered in absence of the product. • The rationales of the design are very clearly stated and well supported by relevant theoretical concepts. • Extensive and reliable source of information to locate particular needs of the users.	• Clear understanding of the problems encountered in absence of the product. • The rationales of the design are clearly stated and supported by relevant theoretical concepts. • Adequate source of information to locate particular needs of the users.	• General understanding of problems encountered in absence of the product. • The rationales of the design are clearly stated and supported by some of the theoretical concepts. However, they are not very relevant. • Acceptable source of information to locate particular needs of the users.	• Limited understanding of the problems encountered in absence of the product. • The rationales of the design are stated in an unclear manner. More theoretical concepts can be drawn to support the design. • Limited source of information to locate particular needs of the users.	• Misunderstanding of the problems encountered in absence of the product. • The rationales of the design are absent. • No source of information is provided to locate the particular needs of the users.
CREATE **Creativity & Innovation**	• The design is highly creative, effective, and comprehensive to meet the needs of the users. • The product is unique with high-quality artistic ideas. Insightful and original ideas are raised. • Excellent in integration and utilization of art concepts and wide variety of materials in designing the product. • Able to apply and connect prior STEAM knowledge to the product very efficiently.	• The design is quite creative and effective to meet the needs of the users. • The product is unique with artistic ideas. • Good in integration and utilization of art concepts and different kinds of materials in designing the product. • Able to apply and connect prior STEAM knowledge to the product efficiently.	• The design is generally creative and effective to meet the needs of the users. • The product is designed with artistic ideas. • Able in integration and utilization of art concepts and materials in designing the product. • Good try to apply and connect prior STEAM knowledge to the product.	• The design is not effective to meet the needs of the users. • The product is lack of artistic ideas. • More art concepts and materials can be applied in designing the product. • Effort is seen in applying and connecting prior STEAM knowledge to the product.	• Inappropriate and infeasible design is shown. • The product has no artistic ideas. • No art concept is applied in designing the product. • No effort is seen in applying and connecting prior STEAM knowledge to the product.

PLAY **Analysis & Interpretation**	• The presentation is delivered in a very smooth manner. • The design is elaborated with detailed analysis and demonstrated very clearly. • All ideas are well-organized and presented with strong evidences to the audience. • Able to respond accurately to questions about the product design raised by the audiences.	• The presentation is delivered in quite a smooth manner. • The design is elaborated with analysis and demonstrated clearly. • Most of the ideas are well-organized and presented with adequate evidences to the audience. • Able to respond to questions about the product design raised by the audiences.	• The presentation is delivered in clear manner, but the process can be smoother. • The main ideas of the design are elaborated and demonstrated satisfactorily. • Many of the ideas are organized and presented with evidences to the audience. • Good attempt to respond to questions about the product design raised by the audiences.	• The presentation is not delivered in clear manner. • There is a lack of elaboration of the design. Illustration of main ideas are limited. • Many of the ideas are in an unorganized manner and presented with not much evidences to the audience. • Limited effort was seen in responding questions about the product design raised by the audiences.	• The delivery of the presentation is very poor. • Explanation of the design is unclear and irrelevant. • All ideas are in an unorganized manner and presented with no evidences to the audience. • Fail to respond to questions about the product design raised by the audiences.
SHARE **Collaboration & Communication**	• Work division is very well-balanced and each group member is able to identify the own role and those of others in the team. • Team spirit is very evident • Excellent in negotiation and collaboration with group members in alignment with inquiry. • Able to share and justify the ideas with strong evidences. • Consistently respect and allow group members to contribute ideas	• Work division is well-balanced and each group member is able to identify the own role and part of those of others in the team. • Team spirit is evident. • Good in negotiation and collaboration with group members in alignment with inquiry. • Able to share and explain the ideas with evidences. • Respect and allow group members to contribute ideas	• Work division is balanced and each group member is able to identify most of the own role, but is not able to know those of others in the team well. • Team spirit is in average. • Effort is seen in negotiation and collaboration with group members in alignment with inquiry. • Able to share the ideas. • Occasionally respect and allow group members to contribute ideas	• Work division is slightly not balanced and each group member is not able to identify the own role and those of others in the team well. • Team spirit is not evident. • Few effort is seen in negotiation and collaboration with group members in alignment with inquiry. • Able to share the ideas, but they are not usually relevant. • Not respect and allow group members to contribute ideas	• Work division is not balanced and each group member is failed to identify the own role and those of others in the team. • Team spirit is not seen. • No effort is seen in negotiation and collaboration with group members. • Not able to share the ideas. • No respect and directly reject group members to contribute ideas
REFLECT **Critique & Revision**	• Able to raise questions critically in a variety of perspectives for further revision of the product. • Able to verify different sources of information from multiple disciplines and refine the problem very efficiently.	• Able to raise questions critically in different perspectives for further revision of the product. • Able to verify different sources of information from multiple disciplines and refine the problem efficiently.	• Able to raise some questions for further revision of the product. • Able to verify different sources of information from multiple disciplines and refine the problem occasionally.	• Very few questions could be raised for further revision of the product. • Limited effort to verify different sources of information from multiple disciplines and refine the problem.	• Not able to raise questions for further revision of the product. • Fail to verify different sources of information from multiple disciplines and refine the problem.

5.4 Conclusion

In this study, the invention kit *Makey Makey* was applied in the STEAM project in the secondary school classroom setting. The delivery of the invention kit *Makey Makey* in the STEAM-based activities stimulated students' hands-on experience through active participation for the generation of creative ideas. The opportunity in designing the human-centred design instruments (HCDIs) for the target groups in the society with the the invention kit *Makey Makey* helps students to learn transforming knowledge and creative ideas in catering the needs of the target group in reality.

The framework from the Runco Ideational Behavior Scale (2001) was adapted to investigate the students' attitude towards creative thinking in this study and it was shown that there was an increase in their attitude change in creative thinking through designing the human-centred design instruments (HCDIs) with the invention kit *Makey Makey* as a result of their participation in the STEAM project. To facilitate the future development of the teaching and learning in STEAM education, a Creative Learning-thinking Model (CLTM) and a set of assessment rubrics was designed for teachers as to evaluate students' creative thinking in the stage of *imagine, create, play, share* and *reflect* in STEAM-based activities, and conceptualize the teaching and learning practices in STEAM education in the future.

5.5 Future work

Professional development workshops could be delivered for in-service teachers to introduce the concept of human-centred design process for STEAM activities. With reference to the research and proven methods, the 10 guiding principles for designing the STEAM-based activities could be considered to share in the workshop for providing frontline teachers a concrete direction in engaging the lesson planning of STEAM related activities. Videos excerpts about the process and experience in creating the HCDIs in classroom settings would be shared with teachers for providing hands-on teaching strategies to stimulate students' creative thinking.

This research is a self-funded pilot study with empirical data in academic base. It brings insights into the relevance of information about the application of creative thinking skills in STEAM-based activities and efforts in strengthening the reform initiatives in STEAM education. The reform initiatives require an organized mobilization of knowledge derived from research, implementation, and evaluation. It is hoped that there are possible future directions to ensure that the conducted STEAM project and findings in this study can inform decisions at policy and strategy levels jointly with government bodies, non-governmental organizations, entrepreneurs, and STEAM experts so as to bring due attention on facilitating students' creative thinking process in education reforms.

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Appendix 1

Runco Ideational Behavior Scale

1. I have many wild ideas.

2. I think about ideas more often than most people.

3. I often get excited by my own new ideas.

4. I come up with a lot of ideas or solutions to problems.

5. I come up with an idea or solution other people have never thought of.

6. I like to play around with ideas for the fun of it.

7. It is important to be able to think of bizarre and wild possibilities.

8. I would rate myself highly in being able to come up with ideas.

9. I have always been an active thinker—I have lots of ideas.

10. I enjoy having leeway in the things I do and room to make up my own mind.

11. My ideas are often considered “impractical” or even “wild.”

12. I would take a college course which was based on original ideas.

13. I am able to think about things intensely for many hours.

14. Sometimes I get so interested in a new idea that I forget about to other things that I should be doing.

15. I often have trouble sleeping at night, because so many ideas keep popping into my head.

16. When writing papers or talking to people, I of-ten have trouble staying with one topic because I think of so many things to write or say.

17. I often find that one of my ideas has led me to other ideas that have led me to other ideas, and I end up with an idea and do not know where it came from.

18. Some people might think me scatterbrained or absent minded because I think about a variety of things at once.

19. I try to exercise my mind by thinking things through.

20. I am able to think up answers to problems that haven’t already been figured out.

21. I am good at combining ideas in ways that others have not tried.

22. Friends ask me to help them think of ideas and solutions.

23. I have ideas about new inventions or about how to improve things.

**A Likert scale is given with each item, ranging from 1 (never) to 5 (very often)*

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Appendix 2

Pre - and Post-Test Questionnaires for Students

<u>Questionnaire of Students' Self-evaluation on Creative Thinking and Innovation*</u>

Section A: Personal information

Your learned instrument(s): ____________________

Year(s) of study: ______

Music Qualification/ Grade: ________________________

Time you spend on playing musical instruments each week: _______________mins/hours

Interest in music making/improvisation: Very strong / strong / Mild / Not interested at all

Section B: Self-evaluation on Creative Thinking and Innovation

<u>Originality</u>

1. I have many wild ideas when participating in group activities.
5. I come up with an idea or solution other people have never thought of.

7. I consider that it is important to be able to think of extraordinary and unique possibilities in playing music with the Human-Centred Design Instrument (HCDI).

10. I am interested to participate in the STEAM project which is based on original ideas.

17. I am able to think up answers to problems that have not already been figured out.

21. I have ideas about new inventions or make further improvement on existing work.

<u>Flexibility</u>

6. I like to play around with ideas for the fun of it.

8. I would rate myself highly in being able to come up with diverse ideas.

14. I often find that one of my ideas has led me to other ideas that have further led me to multiple ideas, and I end up with an idea and do not know where it comes from.

16. I try to think about the STEAM – MakeyMakey project from different perspectives.

19. I am good at combining ideas in assorted ways that others have not tried.

20. My groupmates are used to ask me providing them ideas and solutions.

Fluency

2. The number of ideas that I may offer is used to more than other groupmates.

4. I come up with a lot of ideas or solutions to problems about the Human-Centred Design Instrument (HCDI) during the discussion.

12. Sometimes I feel so interested in a new idea that I forget about other things

13. When having discussion with groupmates in the class, I often have trouble staying with one topic because I think of so many things to express.

15. I may develop a variety of ideas at once.

18. I have always been an active thinker—I have lots of ideas.

Elaboration for creative thinking

3. I often get excited by my own new musical ideas with application in composing.

9. I enjoy the freedom to make up my own mind and brainstorm the ideas in the STEAM project.

11. I am able to concentrate on the instrument creation and composing intensively for many hours.

**** adopted with modification from the framework of the creativity measurement from Runco Ideational Behavior Scale (2001)***

(The original version of the framework of the creativity measurement from Runco Ideational Behavior Scale (2001) is attached in Appendix 2)

**** statements will be randomly arranged by using five-point likert scales –***

1 - "strongly disagree"; 2- "Disagree"; 3 – "Neutral"; 4 – "Agree"; 5 - "strongly agree"

STEAM Project – Focus Group Interview Questions (with students) **Appendix 3**

Interview Guidance Questions for semi-structured interviews with students

Name of Group Members:

- Target User: Kids / Adults / Elderly (Group no : ___)

IMAGINE	***CREATE***	***PLAY***	***SHARE***	***REFLECT***
• What are the actual needs of your product users? Why? • What are the problems they face without your product? • How do you search information for their needs or their products? • What mental images do you visualize in mind for your design? • How do you develop your design into actual product? • What disciplines of STEAM knowledge are involved in your product design? ○ Science ○ Technology ○ Engineering ○ Arts ○ Maths	• What prior STEAM knowledge do you have? Pl specify. • How these STEAM knowledge help your product design? • What learning tools do you use in integrating the STEAM knowledge in your product design? E.g. Youtube, Wikipedia, any websites, product design map, mind-map, flowchart… • How is the product look like? Can you draw a picture for the product? • What materials do you need for the product? Eg. Rubber, wood, wire, foil paper, clips, battery….. • How much time do you need for the product design and completion, including product trial and problems fixing?	• What are the user's needs for your target users (age group) as kids, adults, or elderly eg. bigger word fonts for elderly? More color for kids….. • How do you cater for these needs and include them in your product design? • What special attention you have to pay for your product? Eg. safety, venue setup, avoid eating (edibility), product complexities, user friendliness, setup time? • What major gaps problems do you discover during site inspection or observation? • Why these problems are not anticipated in previous stages? • How do you find the importance of this site visit?	• As a product designer, do you think this teamwork-sharing approach good for your product? • As a product designer, how this others' sharing/ constructive feedback promotes your own product design? • As a product designer, how these sharing increases your openness/ willingness to collaborate with others? • With this sharing, what modifications have you made for the products? • Why do you make such modifications? • What modifications you cannot make now? Why?	• From your reflection, what are the necessary qualities of a designer? How? Why? • How this experience changes your attitude towards "creation, collaboration and communication", as a student designer? • How these "attitude changes" facilitate your future "learning mode" or "career development"? • How does this hands-on design experience improve "reflection for your design process/ thinking process"? • How does this hands-on design experience stimulate your motivation for "creative process VIA communication and collaboration? • What are the differences between this "hands-on design experience" from your "traditional way of learning via lecturing" in school? How? Which one do you like more? Which one makes you more "motivated and engaged" Why?

Appendix 4

香港教育大學
The Education University
of Hong Kong

22 September 2017

Ms LO Kit Mei Jammie
Doctor of Education Programme
Graduate School

Dear Ms Lo,

<u>Application for Ethical Review <Ref. no. 2016-2017-0366></u>

I am pleased to inform you that approval has been given by the Human Research Ethics Committee (HREC) for your research project:

Project title: Human-Centred Design Instrument (HCDI): Creative Thinking and Transdisciplinary Learning in Music Education

Ethical approval is granted for the project period from 1 October 2017 to 30 June 2019. If a project extension is applied for lasting more than 3 months, HREC should be contacted with information regarding the nature of and the reason for the extension. If any substantial changes have been made to the project, a new HREC application will be required.

Please note that you are responsible for informing the HREC in advance of any proposed substantive changes to the research proposal or procedures which may affect the validity of this ethical approval. You will receive separate notification should a fresh approval be required.

Thank you for your kind attention and we wish you well with your research.

Yours sincerely,

Patsy Chung (Ms)
Secretary
Human Research Ethics Committee

c.c. Professor WANG Wen Chung, Chairperson, Human Research Ethics Committee

香港新界大埔露屏路十號
10 Lo Ping Road, Tai Po, New Territories, Hong Kong
T (852) 2948 8888 F (852) 2948 6000 www.eduhk.hk

Appendix 5(i)

Letter of Collaboration

This letter is to confirm the collaboration of the STEAM project (*Makey Makey* module) in the school year 2017-2019 between [redacted] and the principal investigator, Ms Lo Kit Mei Jammie, who is the doctoral student conducting the research project supervised by Dr. Chen Chi Wai from the Department of Cultural and Creative Arts at The Education University of Hong Kong.

Principal

(14 / 1 / 19)

Appendix 5(ii)

Letter of Collaboration

This letter is to confirm the collaboration of the STEAM project (*Makey Makey* module) in the school year 2017-2019 between [redacted] and the principal investigator, Ms Lo Kit Mei Jammie, who is the doctoral student conducting the research project supervised by Dr. Chen Chi Wai from the Department of Cultural and Creative Arts at The Education University of Hong Kong.

Teacher-in-charge of the STEAM Project (*Makey Makey* module)

(2/11/2017)

Appendix 6

THE EDUCATION UNIVERSITY OF HONG KONG

Department of Cultural and Creative Arts

CONSENT TO PARTICIPATE IN RESEARCH

STEAM: How to use Human-Centred Design Instrument (HCDI) in

Creative thinking and Transdisciplinary learning in Music Education?

I ____________________ hereby consent to participate in the captioned research as part of a doctoral dissertation research study conducted by Ms Jammie Lo. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, my right to privacy will be retained, i.e., my personal details will not be revealed.

The procedure as set out in the **attached** information sheet has been fully explained. I understand the benefits and risks involved. My participation in the project is voluntary.

I acknowledge that I have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant ____________________

Signature of participant ____________________

Date ____________________

INFORMATION SHEET

STEAM: How to use Human-Centred Design Instrument (HCDI) in Creative thinking and Transdisciplinary learning in Music Education?

You are invited to participate in a project conducted by Ms Jammie Lo, a doctoral student from The Education University of Hong Kong. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts.

The aim of the study is to examine the creative thinking and transdisciplinary learning in Music Education through an invention kit *Makey Makey* as a Human-Centred Design Instrument (HCDI). You are chosen as one of the participants to design musical instruments for different age cohorts through an invention kit *Makey Makey*. A pilot study will be conducted with pre-test and post-test survey for students at Form one from Oct 2017 to Dec 2018. The researcher will conduct a STEAM class observation which lasts around 1 hour, followed by a 30-minute focus group interview. They will be both video-recorded and audio recorded. The potential benefit of the student is that each of the participants will learn how to use *Makey Makey* to improvise their own song at the end of the project. No potential risk is anticipated in this study.

Your participation in the project is voluntary. You have every right to withdraw from the study at any time without negative consequences. All information related to you will be kept strictly confidential, and will be identifiable by codes known only to the researcher.

Findings of the study will be published in the form of thesis and international music education journal. Sharing session of teaching materials will be disseminated to in-service teachers.

If you would like to obtain more information about this study, please contact Ms Jammie Lo at

If you have any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong.

Thank you for your interest in participating in this study.

Ms. Jammie Lo

Doctoral student from The Education University of Hong Kong.

INFORMATION SHEET

STEAM: How to use Human-Centred Design Instrument (HCDI) in Creative thinking and Transdisciplinary learning in Music Education?

You are invited to participate in a project conducted by Ms Jammie Lo, a doctoral student from The Education University of Hong Kong. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts.

The aim of the study is to examine the creative thinking and transdisciplinary learning in Music Education through an invention kit *Makey Makey* as a Human-Centred Design Instrument (HCDI). You are invited to attend an interview to share the students' engagement and the role of teachers in the STEAM project by using the Makey Makey toolkit. It will be both video-recorded and audio recorded. No potential risk is anticipated in this study.

Your participation in the project is voluntary. You have every right to withdraw from the study at any time without negative consequences. All information related to you will be kept strictly confidential, and will be identifiable by codes known only to the researcher.

Findings of the study will be published in the form of thesis and international music education journal. Sharing session of teaching materials will be disseminated to in-service teachers.

If you would like to obtain more information about this study, please contact Ms Jammie Lo at

If you have any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong.

Thank you for your interest in participating in this study.

Ms. Jammie Lo

Doctoral student from The Education University of Hong Kong.

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Cultural and Creative Arts

CONSENT TO PARTICIPATE IN RESEARCH

From Teacher-Designer to Student-Researcher:
A Study of Learning Process Regarding Creativity in STEAM Education by Using Makey Makey as a Platform for Human-Centred Design Instrument

I ____________________ hereby consent to my child participating in the captioned research as part of a doctoral dissertation research study conducted by Ms Jammie Lo. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts in The Education University of Hong Kong.

I understand that my child's participation in this research study provides an opportunity helping the academic field to have a better understanding of students' creative thinking in the STEAM project. It also helps explore a possible pedagogical framework in the curriculum design of STEAM education in the future.

I understand that information obtained from this research may be used in future research and may be published. However, our right to privacy will be retained, i.e., the personal details of my child will not be revealed. The contact number of my child, provided on voluntary basis hereinafter, would be strictly restricted to the necessary contacts for research purpose and processing only.

The procedure as set out in the **attached** information sheet has been fully explained. I understand the benefits and risks involved. My child's participation in the project is voluntary. I acknowledge that we have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant ____________________

Signature of participant ____________________

Contact Number of participant ____________________

Name of Parent or Guardian ____________________

Signature of Parent or Guardian ____________________

Date ____________________

2

INFORMATION SHEET

From Teacher-Designer to Student-Researcher:
A Study of Learning Process Regarding Creativity in STEAM Education by Using Makey Makey as a Platform for Human-Centred Design Instrument

Your child is now cordially invited to participate in the captioned project conducted by Ms Jammie Lo, a doctoral student from The Education University of Hong Kong. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts.

The aim of the study is to examine the creative thinking in Music Education through an invention kit *Makey Makey* as a Human-Centred Design Instrument (HCDI). You are chosen as one of the participants to design musical instruments for different age cohorts through an invention kit *Makey Makey*. The researcher will conduct a STEAM class observation which lasts around 1 hour, followed by a 1-hour focus group interview. They will be both video-recorded and audio recorded. The potential benefit of the student is that each of the participants will learn how to use *Makey Makey* to improvise their own song at the end of the project. No potential risk is anticipated in this study.

Your child's participation in the project is voluntary. You and your child have every right to withdraw from the study at any time without negative consequences. All information related to your child will be kept strictly confidential, and will be identifiable by codes known only to the researcher. The contact number of your child, provided on voluntary basis therein, would be strictly restricted to the necessary contacts for research purpose and processing only.

Findings of the study will be published in the form of thesis and international music education journal. Sharing session of teaching materials will be disseminated to in-service teachers.

If you would like to obtain more information about this study, please contact Ms Jammie Lo at If you or your child have/ has any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong.

Thank you for your interest in participating in this study.

Ms. Jammie Lo
Doctoral student from The Education University of Hong Kong

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Cultural and Creative Arts

CONSENT TO PARTICIPATE IN RESEARCH

From Teacher-Designer to Student-Researcher:
A Study of Learning Process Regarding Creativity in STEAM Education by Using Makey Makey as a Platform for Human-Centred Design Instrument

I ____________________ hereby consent to participate in the captioned research as part of a doctoral dissertation research study conducted by Ms Jammie Lo. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, my right to privacy will be retained, i.e., my personal details will not be revealed.

The procedure as set out in the **attached** information sheet has been fully explained. I understand the benefits and risks involved. My participation in the project is voluntary.

I acknowledge that I have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Name of participant ____

Signature of participant ____

Date ____

INFORMATION SHEET

From Teacher-Designer to Student-Researcher: A Study of Learning Process Regarding Creativity in STEAM Education by Using Makey Makey as a Platform for Human-Centred Design Instrument

You are invited to participate in a project conducted by Ms Jammie Lo, a doctoral student from The Education University of Hong Kong. This research project is supervised by Dr. Jason Chen, who is an Assistant Professor at the Department of Cultural and Creative Arts.

The aim of the study is to examine the creative thinking in Music Education through an invention kit *Makey Makey* as a Human-Centred Design Instrument (HCDI). You are chosen as one of the participants to design musical instruments for different age cohorts through an invention kit *Makey Makey*. The researcher will conduct a STEAM class observation which lasts around 1 hour, followed by a 1-hour focus group interview. They will be both video-recorded and audio recorded. The potential benefit of the student is that each of the participant will learn how to use *Makey Makey* to improvise their own song at the end of the project. No potential risk is anticipated in this study.

Your participation in the project is voluntary. You have every right to withdraw from the study at any time without negative consequences. All information related to you will be kept strictly confidential, and will be identifiable by codes known only to the researcher.

Findings of the study will be published in the form of thesis and international music education journal. Sharing session of teaching materials will be disseminated to in-service teachers.

If you would like to obtain more information about this study, please contact Ms Jammie Lo at

If you have any concerns about the conduct of this research study, please do not hesitate to contact the Human Research Ethics Committee by email at hrec@eduhk.hk or by mail to Research and Development Office, The Education University of Hong Kong.

Thank you for your interest in participating in this study.

Ms. Jammie Lo
Doctoral student from The Education University of Hong Kong.