Examining Learning Outcomes of Integrated STEM Education from a Career Development Perspective

by

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Statement of Originality

I, LUO, Tian, 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

Due to the growing demand for workers in STEM fields (science, technology, engineering and mathematics), STEM education has been promoted worldwide to spark students' interest in pursuing STEM qualifications and careers. Students' perceptions and attitudes towards STEM careers should thus be evaluated as important learning outcomes. And yet, students often hold biased perceptions of some STEM careers, which may deter them from aspiring to them. Thus, the aims of this study are: 1) to examine students' perceptions of certain STEM careers; and 2) to examine how and to what extent students' perceptions (including stereotypes) of STEM careers impact their career interest via students' self-efficacy and outcome expectations. This study adopted a mixed-method approach, using a qualitative survey with content analysis, interviews with thematic analysis, and a quantitative survey with structural equation modelling. To examine 4th to 6th grade students' perceptions of STEM careers, 564 qualitative surveys (requesting students' drawings and written descriptions of scientists, engineers and technologists at work) were collected and analyzed using content analysis. To facilitate understanding of how perceptions of STEM careers may impact students' career interest and goals, 28 individual semi-structured interviews were conducted, and the data were analyzed using thematic analysis. Moreover, the quantitative surveys were developed or translated and validated to measure students' STEM stereotypes, self-efficacy in STEM activities, STEM outcome expectations and career interest. Afterwards, structural equation modelling (SEM) was performed on the data (n=844) to explore the associations among these four constructs. The results showed that many students tended to relate scientists to lab work, engineers to civil construction, and technologists to technological products, mostly computers. In addition, seven major categories of careers emerged from students' presentations. According to the interviews, students' perceptions of the task or goal of STEM careers shape their outcome expectations and the perceived task or requirement of STEM careers navigate students' self-efficacy, which could contribute to their career interest. The SEM results indicated that STEM stereotypes could negatively predict self-efficacy in STEM activities and outcome expectations, which in turn could predict students' STEM career interest. These results suggest that students' perceptions of STEM careers were biased and some of the perceived career categories of scientists, engineers, and technologists were misplaced. The altruistic aspect of outcome expectations for STEM careers is a very important contributor to STEM career goals. Furthermore, some biased perceptions of STEM careers (e.g., engineers as labors in construction) may lead to negative outcome expectations and thus make students lose interest in STEM careers. In addition, STEM stereotypes can have an indirect impact on STEM career interest via both self-efficacy and outcome expectations. The findings of the study provide explanations for why students' perceptions of STEM careers, including STEM stereotypes, matter in students' career development and highlight the importance of transforming students' biased perceptions of STEM careers.

Keywords: STEM education, STEM careers, career development, career interest, elementary students

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List of Abbreviations

AGFI	adjusted goodness of fit index
AIC	Akaike information criterion
CFA	Confirmatory Factor Analysis
CFI	comparative fit index
CI	career interest
EFA	Exploratory Factor Analysis
GFI	goodness-of-fit index
KMO	Kaiser–Meyer–Olkin
MASS	Math and Science Stigma
NFI	normed fit index
IFI	incremental fit index
IRR	Inter-Rater Reliability
OE	outcome expectations
RMR	root mean square residual
RMSEA	root mean square error of approximation
SCCT	social cognitive career theory

S.E.	Standard error
SE	self-efficacy
SEM	Structural Equation Modelling
STEM	Science, Technology, Engineering, and Mathematics
STEMaSE	Self-efficacy in STEM activities
STEMCI	STEM career interest
STEMOE	STEM outcome expectations
TA	thematic analysis
TLI	Tucker–Lewis index

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1. Introduction

The development of many STEM (science, technology, engineering and mathematics) fields, including new fields, such as artificial intelligence, genetic engineering, and astronomy etc., is crucial for the progress of human wellbeing and economic prosperity. From a macro perspective, the need to nurture talent in STEM fields has become an important concern in many regions and nations (Marginson, Tytler, Freeman, & Roberts, 2013).

It is hoped that through STEM education initiatives, more individuals will be capable and willing to enter the STEM workforce and thus promote economic strength. The concept of STEM education was first brought up and applied in higher education in the United States. Later, STEM has been promoted not only in higher education, but also in elementary and middle schools to unleash more potential in STEM workforce preparedness. Some regional or national governments have promulgated policies or strategies for promoting STEM education, such as the U.S. (National Science Board, 2007), South Korea (Korean Ministry of Education, Science and Technology., 2011), Australia (Education Council, 2015), Hong Kong SAR (Education Bureau, Hong Kong., 2016), China (National Institute of Educational Science, P. R. China, 2017) and Singapore (STEM Inc, 2019).

1.1 Integrated STEM education

Presently, STEM education is most often referred to as an integrated education rather than the education of each discipline. The integration of STEM in education is aligned with the problem-solving process in real-world contexts where science, technology, engineering and mathematics work together closely. STEM is not merely taught as discrete disciplines but also in an integrated way (Office of the Chief Scientist, 2014; National Research Council, 2014). For example, mathematics, engineering, and technology have been integrated into some science standards in China and the U.S. (Ministry of Education, P. R. of China, 2017; NRC, 2012).

Both the formal and informal integrated STEM curriculum or activities have been promoted and implemented in recent years (Education Bureau, Hong Kong, 2016; Japan Society for STEM Education, 2018; So, Zhan, Chow, & Leung, 2017). Integrated STEM is a concept not only applied in curriculum standards or teaching (Johnson, 2013), but also learning. In *Next Generation Science Standards*, STEM integration is evident in student learning through the promotion of scientific and engineering practices (National Research Council, 2013).

Some researchers argue that STEM education constructs meaningful and natural experiences for students to learn and apply mathematics and science by adding engineering elements (Roehrig, Moore, Wang, & Park, 2012). Through the lens of cognitive psychology, STEM education has the merit of enabling concept learning in a connected manner, which promotes meaning making, future retrieving, and transferring of concepts (National Research Council, 2014). In addition, integrated STEM learning can promote students' problem solving and logical thinking abilities (Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016). According to one meta-analysis, the integration of four STEM disciplines had the greatest effect size regarding the increase in achievement, compared to the integration of only two or three STEM disciplines (Becker & Park, 2011).

In another study, students' learning using STEM activities was systematically analyzed by So, Zhan, Chow, & Leung (2017) and a framework of analysing students' practices and learning in STEM activities was developed. The framework was then further used in analysing students' reports in a STEM fair. According to the analysis using the framework, the STEM integration perspective was a valid way to describe students' learning experience in STEM learning activities.

In this study, the concept of STEM is used to represent learning in science, technology, engineering and mathematics, with an emphasis on interdisciplinary (or integrated) STEM learning. Interdisciplinary (integrated) STEM learning is emphasized due to the following reasons: 1) interdisciplinary STEM learning could better reflect the real-world challenges in STEM fields (Johnson, 2013), and 2) most previous studies regarding students' career development in STEM learning (Garriott, Hultgren, and Frazier, 2016; Shen, Liao, Abraham, and Weng, 2014) have not fully addressed the role of integrated STEM learning, as students' learning experiences in these studies have been represented as traditional mathematics and science learning.

1.2 Career development perspective in STEM education

One of the major motives for promoting STEM education is to meet the growing demand for the STEM workforce and make sure that an adequate number of students is capable and willing to enter STEM industries. The low proportion of enrolment and participation in STEM career paths has been a concern in many countries and regions (Marginson, Tytler, Freeman, & Roberts, 2013; OECD, 2008). The trajectory to STEM careers is like an ever-narrowing pipeline, with the number of students interested in STEM subjects decreasing from lower to higher grades (Metcalf, 2010). Specifically, a study on 7820 children from England shows that from age 11 to 14, many students' career aspirations shift from science-related (STEM careers) to non-STEM careers (Sheldrake, 2018).

To look at this issue from an individual perspective, it would be beneficial to analyze the progression of students' career development. In addition, to understand how STEM education can shape students' career development in STEM fields, it has become important to examine STEM learning outcomes through the lens of career development. Career development should be deemed as a life-long process important to all individuals and should not only be taken seriously when students have stepped into adulthood and begun to make major career decisions in their lives. From as early as the childhood years, the perception of, attitudes towards and behaviors related to career development begin to shape their lives; it is a time when children may begin to consciously or unconsciously make career choices (Lent, Brown, & Hackett, 2002). Students made small career-related choices early in their lives, such as choosing the activities they are interested in leisure time or choosing a club/selective course in school. And these tendencies and choices in turn shape their attitudes and future career choices.

STEM education can, from a career perspective, provide students with the chance of gaining understandings and skill acquisition of STEM domains. In students' STEM learning experiences, they should be given the chance to learn about their future career options in STEM fields, including why and how STEM domains matters to human life (National Research Council, 2012). These skills, knowledge, and experiences in STEM learning may enable students to make better-informed career decisions in their future. Therefore, no matter whether a student grow interest in STEM careers, choose STEM major or not, he/she should be given the opportunity to learning about STEM careers and accumulate experiences in STEM learning that help his/her future career-related decision-making.

Among the learning outcomes from STEM learning, the perception of professions/careers in STEM areas is an important factor in students' life-long career development. Some psychological career theories (Brown, 2002) emphasized the importance of "a good match" between individuals and their occupations. Students should have enough information about potential career paths, including the content and requirements of their career options, to make informed career decisions. Ideally, individuals can thus choose to enter/not enter STEM fields based on objective and adequate knowledge of STEM careers.

In K-12 education, STEM education should be designed for all. The knowledge about STEM careers and experiences in STEM learning should be taken as important learning outcomes for all students because they are the foundations for STEM career interest. Though not every student will eventually grow interested in STEM careers, the knowledge of STEM careers and experiences in STEM learning could enable students to be able to make informed career choices of their own.

1.3 Need to measure learning outcomes in STEM education

Measuring learning outcomes is crucial for monitoring the quality of teaching and learning in STEM education. Learning outcomes in STEM education should not only include knowledge and skills, but also attitudes/ values towards STEM and STEM careers (National Research Council, 2014). As argued in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, students should consider:

> *"not only the applications and implications of science and engineering in society but also the nature of the human endeavor of science and engineering themselves. They likewise*

need to develop an awareness of the careers made possible through scientific and engineering capabilities." (National Research Council, 2012)

Nurturing experts in STEM areas has been one of the main goals in STEM education in the U.S., Hong Kong, and many other countries/regions in the world. The Hong Kong STEM education guideline emphasized that STEM education should help students "explore and learn about STEM-related careers" (Education Bureau, Hong Kong., 2016). The willingness of entering STEM careers and STEM identity were also highlighted as important outcomes of integrated STEM education for students (National Research Council, 2014).

While learning outcomes, a concept widely used in the literature, could include knowledge gains, skill mastering, perceptions, and attitudes development etc., the concept of learning outcome used in this study specifically focus on the perceptions and attitudes regarding STEM and STEM careers. Students' perceptions of and attitudes towards STEM learning and STEM careers have been recognized as important learning outcomes of STEM education (National Research Council, 2012, 2014). In addition, the attitudinal change regarding STEM learning and STEM careers were measured to evaluate efficacy of various STEM interventions and programs (Falco & Summers, 2017; Guzey, Harwell, & Moore, 2014; National Research Council, 2014).

Compared to disciplinary learning in science and math, there are fewer studies determining the effect of integrated STEM education on student learning (Harwell et al., 2015; Jayarajah, Saat, & Rauf, 2014). The limitation of existing tools for measuring learning outcomes is hindering the development of STEM education (Saxton et al., 2014). Measuring learning outcomes in integrated STEM learning is a challenging task. Historically, assessment treats each STEM discipline in isolation, such as assessing learning outcomes in mathematics and science (National Research Council, 2014).

1.4 Aims and objectives of the current study

From career development perspective, the researcher of the current study hopes to explore how students' STEM career interest/ goals are formed, with a special focus on their perceptions of STEM careers and what role do their perceptions of STEM career play in the formation of students' STEM career interest/goals. In seeking the answers, the researcher treats STEM learning as integrated learning because the integration is emphasized in STEM education. Meanwhile, the current study revised and developed a series of measuring tools, which also can contribute to the literature regarding measurement of learning outcomes in STEM educations.

The aims of the current study are twofold: First, to examine students' perceptions of STEM careers; And second, to examine how and to what extent students' perceptions (including stereotypes) of STEM careers impact their career interest/goals via students' self-efficacy and outcome expectations.

In detail, the objectives of the study are: first, to examine students' perceptions of STEM careers, including the existence of stereotypes, diversity of their careers, and the content of their work; second, to examine perceived associations among students' perceptions of STEM careers (including STEM stereotypes), STEM self-efficacy, STEM career-related outcome expectations, and students' career interest and goals; and third, to explore the associations among students' careers STEM stereotypes, STEM self-efficacy, STEM career-related outcome expectations, and STEM career interest.

To summarize, the present study examines some learning outcomes from integrated STEM education regarding career development perspectives. This study focuses on the role that students' perceptions of STEM careers play in their construction of STEM career interest under the integrated STEM perspective, which has the potential to fill some research gaps regarding measurement in STEM education and the overlapping field of STEM education and career development. This study can also provide valuable information regarding how and why students aspire to, show interest, or even reject a STEM career, which will be beneficial for STEM educators, curriculum developers and career educators.

1.5 Structure of the thesis

Chapter 1 provide an overview of the background of the study, which is also the perspectives from which this whole study was designed and structured. The aims of the study were also made clear in chapter 1. Chapter 2 presents a literature review based on the aims and perspectives of the study. Chapter 3 provides the theoretical framework developed upon the foundations of the literature review by illustrating the summarized research gaps. The research questions, which were based on the research gaps, were also poposed in chapter 3. Chapter 4 presents the research design, methods and how these address to the research questions. Chapter 5 is organized to introduce the results of the study from the applying the methods. Afterwards, chapter 6 presents the discussion of the findings and how they associate with each other. Last but not the least, chapter 7 summarized the conclusions and explores their contributions to the literature, as well as implications for the education community, limitation of the study and suggestions for future research.

2. Literature review

Through the lens of career development, STEM education has the potential to provide learning experiences and career information that students may refer to when they are making career decisions. The focus of this study is to understand how students develop an interest in STEM careers or reject them, especially under the consideration that perceptions of STEM careers can have an important influence on students' STEM career interest (Archer et al., 2013; DeWitt, Archer & Osborne, 2013; van Tuijl & van der Molen, 2016). However, the mechanism behind the influence of perceptions of STEM careers on students' career interest remains unclear.

This chapter discussing the theoretical framework includes a comprehensive literature review from three perspectives. The chapter begins by reviewing related theories in career development as the theoretical foundation for this study, followed by a literature review regarding how students develop their STEM career interest. Moreover, the existing measurement and instruments for related learning outcomes in STEM education are also reviewed. Based on the literature review from these three aspects, research gaps and questions are proposed at the end of this chapter.

Before diving into the literature review, some frequently used terms in this thesis with similar meanings need clear conceptualization, including perceptions, beliefs, attitudes, and orientations. First, "perceptions of STEM careers" is used more frequently in this study when referring to views about STEM careers because the word perception is used most frequently in the literature regarding students' views of STEM careers (e.g. scientists). Perception is defined as "result of becoming aware of objects, relationships, and events".

Moreover, beliefs mean “an association of some characteristic or attribute, usually evaluative in nature, with an attitude object” (VandenBos, G. R. & American Psychological Association, 2015). In previous literature, perceptions and beliefs were used interchangeably (e.g., stereotypical beliefs/perceptions). However, to make the concepts clearer in this study, perceptions are used to refer to views about careers, while beliefs are used referring to other views, including views about self or relation of self and another object/issue, such as self-efficacy beliefs. The word belief is used in this thesis in the term “self-efficacy belief” to be consistent with some literature regarding self-efficacy. It should be noted that the term “self-efficacy belief” has the same meaning as self-efficacy.

On the other hand, attitudes refer to “evaluation of an object, person, group, issue, or concept on a dimension ranging from negative to positive”, which is more general, enduring, and summative (VandenBos, G. R. & American Psychological Association, 2015). Compared to attitudes, perceptions are usually more fragmented and more likely to change.

Last but not least, orientation, which means “an individual’s general approach, ideology, or viewpoint” (VandenBos, G. R. & American Psychological Association, 2015), is used in this study to refer to an individual’s tendency or inclination. Specifically, career orientation in this study indicates one’s inclinations in choosing careers, which is similar to career goals, the same as does in Nugent et al.’s study (2015). Specifically, when used in describing or discussing classical literature of career theory by Gottfredson (2002), the term is used to describe certain stages of considering career choices when in each stage, an individual emphasize a certain aspect of consideration regarding choosing a career (e.g. “stage 2: orientation to sex roles”).

2.1 Foundations of theories in career development

There are several general theories explaining people's career development, career behaviours and career choices. Unlike many theories emphasizing personal traits (some are genetic) such as Holland 's theory (1997), social cognitive career theory (SCCT) emphasizes the individuals' construction of interests and goals based on social interaction, which is more closely related to education. SCCT was developed based on the social cognitive theory proposed by Bandura (1986) and was then further developed by Lent et al. (2002, 2015). Figure 1 shows the choice model of SCCT. In this model, career-related behaviours are influenced by self-efficacy beliefs, outcome expectations and goals. People's goals in turn are influenced by self-efficacy, outcome expectations and personal interests. In addition, interests have inputs from self-efficacy and outcome expectations, both of which are contributed to by one's learning experiences. Finally, outcome expectations are also predicted by self-efficacy beliefs.

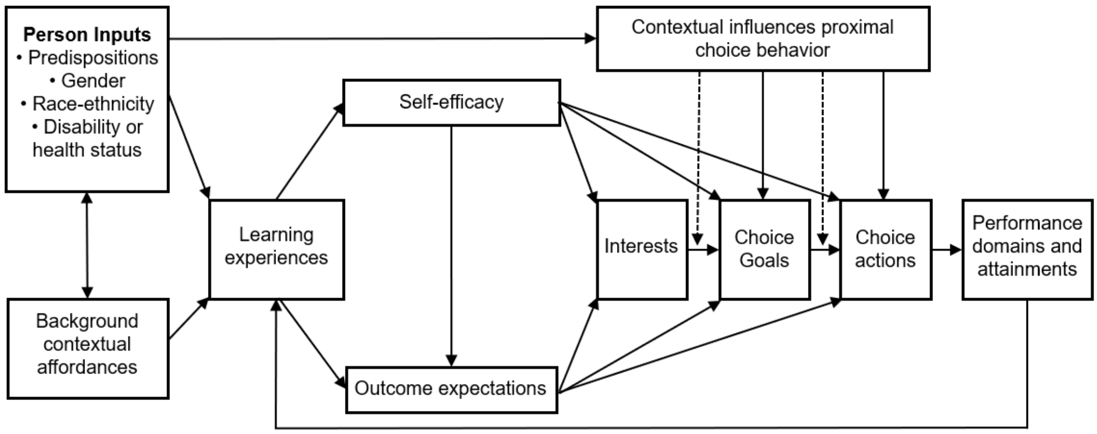


Figure 1. Social Cognitive Career Theory (Lent, Brown, & Hackett, 2002)

Career interest is conceptualized as individuals' general interests in choosing certain careers. For example, STEM career interest, a term which is frequently used in this study, means one's interest in choosing STEM careers in the future. Though according to this conceptualization, STEM career interest is less strongly than career aspirations/choices goals, career interest should be positioned along with choice/goals in the SCCT model. According to the clarification about individual interest and situated interest (Renninger, K. A., & Hidi, S., 2011), career interest in this study belong to individual interest, as it is relatively long-term, persistent, and well-developed interest in some careers.

Although the model in SCCT has identified many key constructs, perceptions of career options, which is very important in one's career development, are not mentioned. Perceptions of careers, especially misconceptions and stereotypes may preclude students' pursuit of certain careers from early adolescence.

There are also theories about career choice and development that address the role of perceptions of careers. In the early work of Parsons' tripartite model (1909), which is usually cited as the origin of career choice and development theories, Parson argued that a well-made career decision requires three factors: 1) a clear understanding of oneself; 2) a knowledge of different lines of work; and 3) a true reasoning among these two factors. Although these arguments were not a theory, they provided a valuable foundation for later theories, especially theories of trait and factor which emphasize the fit between the trait of an individual and the factor leading to success. Many researchers now acknowledged that people usually negotiate between knowledge of careers and themselves (Swanson & Fouad 2015).

In Gottfredson 's theory of circumscription, compromise, and self-creation (2002), individuals form images of occupations and assess the compatibility between their self-concept and the images of occupations when making career choices. Here, the image of occupations is not merely an individual image of each occupation, but a "cognitive map of occupations," in which the occupations are laid out according to dimensions such as prestige and masculinity-femininity level, etc. Unlike many career development theories, Gottfredson's theory (2002) pays close attention to the development of children and suggests individuals have different orientations regarding career choices at different stages in life. As individuals gradually develop, students may most strongly reject the occupational choices that conflict most with their self-concept. For example, from age six to eight, (stage 2: orientation to sex roles) children begin to form the concept of sex roles and tend to choose careers that "fit" their gender and reject the careers that seem "wrong" for their gender. And from age nine to 13 (Stage 3: Orientation to social valuation), children begin to incorporate social class and ability to their self-concept and reject careers with low social prestige. As Gottfredson (2002) argues, the most significant career compatibility concern is masculinity-femininity, followed by social status, fulfilment of activity and personality preference.

Gottfedson' s theory put more emphasis on the developmental psychology aspect of career development. Thus, it may have its advantages when explaining early career development for children or adolescence. In addition, the theory extracts some features of individuals' inner negotiation process when making career choices, like circumscription, making it very suitable to be used as a conceptual framework for analysing interactive or dynamic data like interviews.

2.2 Development of students' STEM career interest

Many studies on students' development of STEM career interest or intention adopt a retrospective method and find the relationship between students' early STEM experiences, including self-initiated activities early in their lives (Maltese & Tai, 2010; Maltese, Melki, & Wiebke, 2014), participation in out-of-school science (Dabney et al., 2012) or STEM activities (Sahin, 2014), may contribute to their STEM career interest, intention or choices later in their lives.

The development of students' STEM career interest may be a process involving many psycho-educational factors. In a longitudinal case study examining how an informal science program influenced the career development of 152 young women from the U.S. (Fadigan & Hammrich, 2004), the participants gave several reasons, including having university staff for communication, learning job skills and informal science learning, for their STEM-related career decisions. A qualitative exploration of how students justify their decisions about STEM-related career choices in upper secondary level showed that career-related decision making involved negotiating among various interests, self-concept, and expectations of social relations (Holmegaard, 2015). Another qualitative study involving STEM career decision-making process of 12 high school students from Taiwan, China indicated that four domains matter in this process, namely personal input, contextual variables, outcome expectations, and self-efficacy. Yet there are very few studies that systematically explain how students' career intentions or choices are influenced by their perceptions of STEM careers, especially when many young students may have stereotypes, biased perceptions or lack perceptions of STEM careers.

2.2.1 Perceptions of STEM careers and students' career development

Perceptions of STEM careers may influence students' career interest, goals and future career choices. Perceptions of STEM careers here is a broad concept, including but not limited to the content and requirement of their work, features of the STEM professionals and their work, etc. Blackhurst, Auger, and Wahl (2003) argued that the inaccurate perceptions of the requirement of careers may well influence early career aspirations. Fadigan and Hammrich (2004) claim that students' knowledge about possible options and the lack of information about careers may limit their choices. Some researchers have also argued that perceptions of

STEM careers play an important role in students' career development. (Archer et al., 2013; DeWitt, Archer, and Osborne, 2013; van Tuijl & van der Molen, 2016). Although some quantitative evidence has indicated that students' image of scientists does not directly relate to their science aspirations (DeWitt et al., 2013), indirect effect or more complex influences could exist. For example, Holmegaard, Madsen, and Ulriksen (2014) investigated students' motivation in choosing their majors and found that non-STEM choosers think that STEM majors are "stable, rigid and fixed", suggesting that negative perceptions of STEM majors may hinder students' pursuit of these majors.

Many empirical studies have found that different aspects of perceptions of STEM careers can impact students' career intentions and interests. Although STEM careers are believed to provide less opportunity to help others and collaborate (Boucher, Fuesting, Diekman, Murphy, 2017), the aspect of working with or helping others in their STEM careers may enhance students STEM career interest. Likewise, Weisgram and Bigler (2006) found that students' perceived altruistic values of science careers could predicted students' interest in science. A qualitative study by DeWitt, Archer, and Osborne (2013) revealed that students may believe science as being for "specialists" or "not for me" and preclude science as a potential career choice.

Specifically, one of the prominent issues related to students' perceptions of STEM careers is the existence of stereotypes. Stereotypes are perceptions about a group of people that are over-generalized, often negative (Matsumoto, 2009; VandenBos, & American Psychological Association, 2015). STEM stereotypes are the stereotypical perceptions about people working in STEM fields. In the present study, STEM stereotypes are treated as a component of perceptions of STEM careers.

Students' STEM stereotypes have long been an issue of discussion in the literature. Previous studies have found that students held stereotypes of some STEM careers. For example, some middle school students perceive scientists as people working indoors wearing lab coats and glasses (Fralick, Kearn, Thompson, & Lyons, 2009). Researchers have also found that students hold the stereotypical perception of engineers as doing handy work like fixing, installing, and building (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Lachapelle, Phadnis, Hertel, & Cunningham, 2012). According to surveys conducted in Organization for Economic Co-operation and Development (OECD) countries, some students view professionals in science and technology as "doing boring, uninteresting work in unpleasant surroundings, cut off from other people" (OECD, 2008). And some researchers compared high school students' perceptions of some STEM and non-STEM careers and found that the students think that STEM careers are less people-oriented and less creative than non-STEM careers (Masnick, Valenti, Cox, and Osman, 2010).

STEM stereotypes may somehow have an impact on students' career interest and intentions. Gottfredson (1981) argued that occupational stereotypes can influence the process that individuals use to narrow down their career choices. Likewise, some researchers have stated that occupational stereotypes may influence the perceived match between the individual and the career (Nassar-McMillan, Wyer, Oliver-Hoyo, and Schneider, 2011). Researchers in science education also suggest that students' STEM stereotypes may have a negative influence on students' STEM career interest (Archer et al., 2013; DeWitt, Archer, and Osborne, 2013; van Tuijl & van der Molen, 2016). Archer et al. (2013) found that some students reject science as a career choice because they may think that people in science careers are "geeks" or "boffins." And the stereotypical perceptions of science careers (e.g., “clever/brainy”, “not nurturing” or “geeky”) held by students prevent upper-elementary girls from aspiring to science careers (Archer et al., 2013). As summarized in a review on career development in STEM subjects, STEM stereotypes are a problem to be tackled in students’ career development (van Tuijl & van der Molen, 2016). The potential effect of students’ STEM stereotypes and career interest could thus be hypothesized based on the above evidences.

However, there is still a lack of studies investigating whether and to what extent students’ STEM career interest can be predicted by their STEM stereotypes. This is one of the major gaps to be filled in this study.

2.2.2 Self-efficacy, outcome expectations and their impact on STEM career interest

The contributing effect of self-efficacy and outcome expectations on career interest has been well-explained in social cognitive career theory (SCCT). Self-efficacy, as conceptualized first by Bandura (1977, 2010), means beliefs about an individual’s own “capabilities to produce effects.” Self-efficacy is a positive contributor to students’ effort, choices, and persistence in their learning (Zimmerman, 2000). In this study, STEM self-efficacy refers to students’ beliefs about their capabilities in STEM learning activities. According to Bandura (1977, 1986) and Lent, Brown, and Hackett (1994), outcome expectations means the expected results of a particular action, or simply put, the expectations about “if I do this, what will happen?” STEM career interest in the present study is defined as individuals’ general interests in choosing STEM-related careers, such as scientists, engineers or technologists.

According to SCCT, self-efficacy beliefs and outcome expectations can positively contribute to career-related intentions or goals, and self-efficacy beliefs also have a positive impact on outcome expectations (Lent et al, 2002; 2015). The associations among these constructs, were based on the social cognitive theory developed by Bandura (1986) and Brown and Lent (2015). Similar to (but weaker than) career aspirations, career interest should be positioned along with choice/goals in the SCCT model. According to a literature review done by Betz (2008), the SCCT model has been widely applied and confirmed valid in STEM education (Lin & Deemer, 2019; van Tuijl & van der Molen, 2016). According to another meta-analysis with data from 143 studies, the associations among self-efficacy, outcome expectations and career interest have received overall support in disciplinary STEM education (Lent et al., 2018).

However, there are only a few studies examining the relationships among self-efficacy, outcome expectations and career interest through the lens of an integrated STEM education perspective (Nugent et al., 2015; van Aalderen Smeets, Walma Van Der Molen, & Xenidou Dervou, 2018). Nugent et al. (2015) found that 10- to 14-year-old students' interest in STEM could predict their self-efficacy (standardized coefficient = 0.913) and outcome expectations (standardized coefficient =0.998), and their career outcome expectations could in turn predict their STEM career orientations (standardized coefficient = 0.609). In Nugent et al.'s model (2015), interests were taken as a predictor of self-efficacy and outcome expectancy, which is not consistent with the SCCT model. In addition, the model added prior knowledge in STEM domains as one of the outcome variables, which may not be very valid to taken as a single construct according to its relatively low coefficient alpha (0.463). The adding of prior knowledge as an outcome variable into the model may also be the cause of the insignificant predicting effect of self-efficacy on career orientation.

In van Aalderen Smeets, Walma Van Der Molen, & Xenidou Dervou' s study (2018), self-efficacy directly predicted STEM intention, which is similar to career goals, (standardized coefficient = 0.536) and indirectly via achievement. This model result is quite different from Nugent et al.' s model (2015) in that self-efficacy directly predicts STEM career intention (orientation) and achievement could also predict career intention (standardized coefficient = 0.086).

2.2.3 STEM stereotypes and their impact on career interest through self-efficacy and outcome expectations

STEM self-efficacy and outcome expectations might be predicted by an individuals' stereotypes about STEM careers. STEM stereotypes may have their influence on STEM self-efficacy because stereotypes of STEM careers may provoke a perceived mismatch between self and STEM careers, and therefore prevent students from developing STEM self-efficacy. As found in a study by Cheryan, Siy, Vichayapai, Drury, and Kim (2011), the perceived dissimilarity between students themselves and stereotypical STEM professionals predicted female undergraduates' perceived success in computer science, indicating that STEM stereotypes may lead to lower STEM self-efficacy.

Theoretically, STEM career-related outcome expectations are based upon, or derived from their perceptions about STEM careers, including STEM stereotypes. People holding more negative stereotypes of STEM careers may also tend to expect more negative outcomes of STEM careers. For example, students who had stereotypes that scientists' experiments sometimes cause explosion, fire or producing deadly matter may well expect that to be a scientist is an unsafe career choice. Holmegaard, Madsen, & Ulriksen (2014) found that a student interested in technical engineering while also holding negative stereotypes of engineers had outcome expectations that engineers work in isolation.

Garriott et al.'s study (2016) showed that high school students' STEM stereotypes negatively predicted their mathematics/science self-efficacy which further impacted their mathematics/science interest and this interest in turn predicted the students' STEM career goals. In their study, the possible effect of STEM stereotypes on outcome expectations was not explored.

The literature reveals that stereotypes may have an impact on both self-efficacy and outcome expectations. Shen, Liao, Abraham, and Weng (2014) found that students' internalized occupational stereotypes could directly predict self-efficacy, outcome expectations and career interest in stereotypical occupations (mostly STEM occupations such as engineers). Although in Shen, Liao, Abraham, and Weng's study (2014), internalized occupational stereotypes are defined as culture-related occupational stereotypes for Asian American college students, which are different from STEM stereotypes defined in this study, the mechanism that stereotypes have an effect on self-efficacy and outcome expectations should be similar.

2.3 Examining learning outcomes related to students' career development in STEM fields

Perceptions of STEM professionals/ careers, outcome expectations, self-efficacy in STEM activities, and STEM career interest should be viewed as important learning outcomes in STEM education. Although many studies in STEM education do not adopt a career development perspective, some studies do examine some important constructs for students' career development, including perceptions of STEM careers (including stereotypes of STEM careers) and attitudes towards STEM/STEM careers (self-efficacy, outcome expectations, career interest and goals). It is thus necessary to review the existing literature measuring these learning outcomes dealing with measurement in both STEM education and career development. Students' attitudes and perceptions can be assessed by direct observation, rating by others and self-reports, among which the self-report is the most used method. Using self-reports to measure attitudes refers to adopting questionnaires, interviews and stimulated recalls etc.

2.3.1 Examining students' perceptions of STEM careers

The perceptions of STEM careers or professions in STEM areas are very important for students' career development. It would be ideal if individuals could make career choices based on unbiased perceptions of careers and choose majors and careers that they like and are good at. A good match between individuals and their career is stressed in many career development theories (Brown, 2002). Researchers have argued that a narrow perception of science careers could be perceived as a barrier in students' pursuit of science career paths (DeWitt, Archer, & Osborne, 2013).

The research on students' perceptions of STEM careers dates back to the 1980s, with most studies focusing on students' perceptions of scientists. Most previous studies on students' perceptions of STEM careers (Knight & Cunningham, 2004; Farland-Smith, 2012; Farland-Smith, 2006; Finson, Beaver, & Cramond, 1995) have adopted drawing task such as the Draw-A-Scientist-Test (DAST) developed by Chambers (1983) to explore students' perceptions.

The instruments examining students' perceptions of scientists/engineers have evolved from asking students to draw scientists/engineers to drawing a scientist/an engineer at work and some recent instruments have also asked students to write descriptions of their drawn scientists' or engineers' work (Chambers, 1983; Emvalotis & Koutsianou, 2018; Farland, 2006; Hillman, Bloodsworth, Tilburg, Zeeman, & List, 2014; Huber & Burton, 1995; Karatas, Micklos, & Bodner, 2011; Laubach, Crofford, & Marek, 2012; Schibeci & Sorensen, 1983). Studies examining students' perceptions of scientists and engineers using DAST or its revised versions have evolved from an earlier stage of focusing only on the stereotypical features of these STEM professionals as people (Chambers, 1983; Huber & Burton, 1995; Schibeci & Sorensen, 1983) to including the features of their work (Emvalotis & Koutsianou, 2018; Farland-Smith, 2016; Hillman, Bloodsworth, Tilburg, Zeeman, & List, 2014; Karatas, Micklos, & Bodner, 2011; Laubach, Crofford, & Marek, 2012).

Many studies have shown that elementary and middle school students may hold inadequate or stereotypical perceptions of scientists and engineers (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Fralick, Kearn, Thompson, & Lyons, 2009; English, Hudson, & Dawes, 2011; Karaçam, 2016). In addition, elementary students' perceptions of the work of engineers also tend to be stereotypical and biased, focusing on handy work such as repairing , installing, building, fixing, or using vehicles (Capobianco, Diefes-Dux, Mena, & Weller, 2011;Lachapelle, Phadnis, Hertel, & Cunningham, 2012).

Apart from the instruments using drawing tasks, quantitative instruments such as Likert-type questionnaires have also been developed to examine students' STEM stereotypes. The Image of Science and Scientists Scale (ISSS) is an instrument based on Mead & Metraux 's study (1957) on students' written responses regarding science and scientists. In addition, the

Stereotypes of Scientists (SOS) Scale developed by Wyer, Schneider, Nassar-McMillan, & Oliver-Hoyo (2010) and have been validated on college students using two factors (professional competence and interpersonal competence) and good reliability (Cronbach's alpha = .84 for professional competence and Cronbach's alpha = .79 for interpersonal competencies).

Another single-factor instrument developed by Garriott et al. (2016) is called Math and Science Stigma (MASS) Scale, which focuses on students' stereotypes of people who work in STEM fields in general. In this scale, students are asked to make evaluations of people who work in STEM fields. For example, students were asked whether they thought people working in STEM fields "are not attractive" or "have bad hygiene." A group of experts in career development developed the 40-item initial version of MASS before the scale was administered to 341 high school students. The result revealed that eight items formed a single factor structure. The 8-item MASS was then analyzed using confirmatory factor analysis on 358 high school students and showed single-factor structure (Cronbach's alpha of .93). Among the eight items, four items focused on the "less-people oriented" aspect of STEM stereotypes, consistent with the findings in Masnick, Valenti, Cox, and Osman's (2010) study. One of the advantages of Likert-type questionnaires is their ability to collect and analyze data on a large scale. On the other hand, such questionnaires cannot collect deep or rich information about students' perceptions.

2.3.2 Examining students' attitudes towards STEM learning and careers

In this section, the measuring of constructs that are crucial to this study were reviewed, mainly include students' self-efficacy in STEM learning, STEM outcome expectations, and career interest. There are some qualitative studies examining students' career-related attitudes. For example, Shoffner, Newsome, Barrio Minton, and Wachter Morris (2015) interviewed middle school students about their career-related outcome expectancies using a focus group method. They found that in addition to the physical, social and self-outcome expectations as classified by Bandura (1986), students mentioned two additional types of outcome expectations, namely generativity and relational outcomes. On the other hand, using questionnaires is more suitable for large-scale investigations. Several researchers have developed surveys assessing STEM attitudes and many of them assess attitudes towards both STEM learning and STEM careers (Guzey, Harwell, & Moore, 2014; Kier, Blanchard, Osborne, & Albert , 2014; Koyunlu, Unlu, Dokme, & Unlu, 2016; Mahoney, 2009; Oh, Jia, Lorentson, & LaBanca, 2013; Toker & Ackerman, 2012; Tyler-Wood, Knezek, & Christensen, 2010; Unfried, Faber, Stanhope, & Wiebe, 2015).

Self-efficacy as a concept has been applied in education measurement for decades. In STEM disciplines, surveys on self-efficacy in STEM disciplines such as math, science, and engineering have been developed and used in various studies (Britner, 2002; Mamaril et al., 2016). In addition, self-efficacy has been taken as one dimension of motivation in several science motivation surveys (Bryan, Glynn, & Kittleson, 2011; Glynn, Taasoobshirazi, & Brickman, 2009; Tuan, Chin, & Shieh, 2005).

Nugent, Barker, Grandgenett, and Adamchuk (2010) revised the Motivated Strategies for Learning Questionnaire developed by Pintrich, Smith, Garcia, & McKeachie, l991) into a survey to measure students' self-efficacy in learning robotics and GPS/GIS, with items focusing on motivation to learn, perceived value (mathematics, science, GPS/GIS technologies, and robotics) and learning strategies (problem solving and teamwork). The survey has good reliability (Cronbach's alpha from .64 to .88) and confirmatory factor analysis showed that it has fit indices close to acceptable fit criteria. However, this survey is specific to only GPS/GIS and robotics learning and needs revisions under other circumstances.

Unfried, Faber, Stanhope, and Wiebe (2015) developed two versions of one survey to measure students' attitudes toward STEM and STEM careers, namely Upper Elementary S-STEM for 5-6th grade students and Middle/High S-STEM for 6th-12th grade students. The instrument was developed upon a theoretical foundation of social cognitive career theory, with content of expectancy-value, self-efficacy and career interest in STEM. However, the items on each dimension treat science, mathematics and technology/engineering as disciplinary learning with no items dealing with the interdisciplinary features of STEM. Guzey, Harwell, and Moore (2014) developed a survey assessing upper elementary students' STEM self-efficacy and expectancy-value beliefs. However, there are only four items on self-efficacy in this survey, each focusing on science, technology, engineering and mathematics, which is insufficient for uncovering this integrated feature in STEM education.

There are very few measures for career-related outcome expectations. In Hazari, Sonnert, Sadler, and Shanahan (2010)' s study, they used a measure assessing students' general career-related outcome expectations. Although there are some surveys regarding STEM attitudes with a few items on outcome expectations (Kier, Blanchard, Osborne, & Albert, 2014; Unfried, Faber, Stanhope, and Wiebe, 2015), so far, there is yet no validated measuring instrument in the literature for STEM career-related outcome expectations.

There are some existing surveys for STEM career interest, and yet their definitions of career interest were inconsistent and include a series of attitudes towards STEM careers rather than a single construct. For example, Tyler-Wood, Knezek, and Christensen (2010) developed two scales, namely the STEM Semantics Survey and the STEM Career Interest survey, to assess students' interest in STEM subjects and careers respectively. The surveys were validated on 6^{th} - 8^{th} grade students and showed good construct and criterion-related validity (Tyler-Wood, Knezek, & Christensen, 2010). The disadvantage of both surveys is that they are not linked with any existing theoretical framework. In addition, STEM career interest survey has five items each associating an attitudinal evaluation of STEM carers (e.g., boring/interesting, means nothing/ means a lot), which is very different from interest in STEM careers.

In addition, the STEM career interest survey (STEM-CIS) (Kier, Blanchard, Osborne, & Albert, 2014), based on social cognitive career theory, can assess 6-8th grade students' career-related attitudes in STEM areas, including self-efficacy, personal goals, outcome expectations, interest, personal inputs, contextual supports, and barriers. The survey was found to be a reliable instrument with four subscales in four STEM disciplines. Moreover, this survey was later adapted into Turkish (Koyunlu Unlu, Dokme, & Unlu, 2016).

Oh, Jia, Lorentson, & LaBanca (2013) developed a survey for high school students called the Educational and Career Interest in STEM, with 12 items measuring interests in STEM disciplines and eight items measuring overall interests in STEM. The shortcomings of the scale, however, was that the items of engineering were deleted due to the participant students' lack of familiarity with engineering. In addition, Toker & Ackerman (2012) developed the STEM Interest Complexity scale for college students. The scale emphasized interest in very specific careers, which was actually more suitable for adults.

3. Theoretical framework

The theoretical framework of this study was built upon the research gaps summarized from the literature review. This chapter firstly elaborates the summarized research gaps through the lens of the aims of the study. Second, a proposed theoretical framework was introduced. Last, the research questions, which could address the research gaps, were proposed in this chapter.

3.1 Research gaps

The research gaps in this study are described under three themes: 1) examining students' perceptions of STEM professionals, 2) exploring the association between students' perceptions (including stereotypes) of STEM careers and career interest; and 3) assessment of variables that are crucial to students' career development.

3.1.1 Research gap in examining students' perceptions of STEM careers

One research gap in the existing literature is the lack of studies examining students' perceptions of technologists and their work. Technologists use STEM knowledge and skills (such as science and mathematics knowledge and skills) in their work and collaborate closely with scientists and engineers. Technologists should be viewed as an important type of STEM professional. Many students may enter STEM fields working as technologists. In addition, there are very few studies comparing students' understandings of several STEM professionals at one time (Fralick, Kearn, Thompson, and Lyons, 2009). In the present study, students' drawings and written descriptions of scientists, engineers, and technologists were collected and analyzed together, which can provide valuable information regarding the perceived differences among these careers. These three careers were included in this study because they comprise a large proportion of STEM careers and they all use a considerable amount of knowledge and skills in STEM disciplines in their work.

3.1.2 Research gap in the association between students' perceptions of STEM careers and career interest

According to the literature review, there is a research gap in associating students' perception of STEM careers and other constructs related to career development (self-efficacy, outcome expectations, STEM career interest /goals). The mechanism how students' perceptions of STEM careers may influence career interest and goals, possibly via self-efficacy and outcome expectations remains unclear.

In addition, there has been evidence indicating that STEM stereotypes, which is part of perceptions of STEM careers, shed its influence on STEM career interest via self-efficacy (Garriott et al., 2016). However, the existence and extent of the effect of STEM stereotypes on self-efficacy and outcome expectations, which in turn may influence STEM career interest, need further exploration, especially under the integrated STEM perspective. These research gaps were also illustrated in Figure 2.

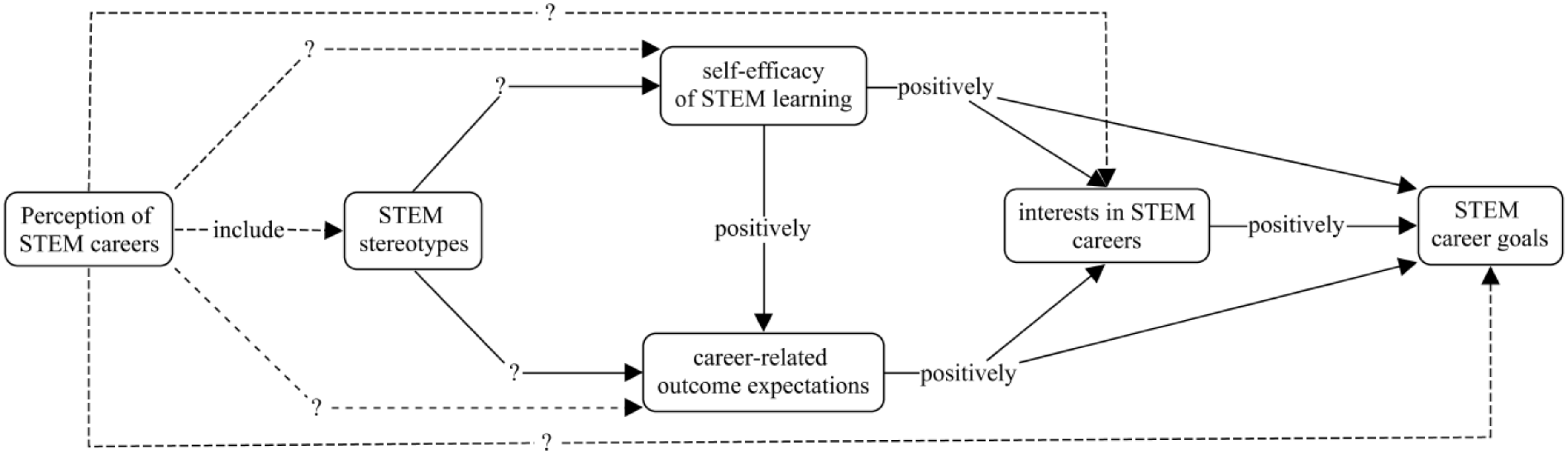


Figure 2. Theoretical framework of the study

[A line without a question mark shows the established association in the literature. A line with a question mark (?) shows the research gap, which is an association that needs to be explored in this study. A solid line (shown by ——) indicates a quantitative relation, while a dotted line (shown by - - - -) indicates a qualitative association.]

3.1.3 Research gap in assessment of STEM career-related variables

According to the literature review, there is a research gap in assessment in STEM career-related variables, which are the variables examined in this study. Specifically, there is lack of assessment instruments suitable for young students on their self-efficacy in STEM activities, STEM career-related outcome expectations and STEM career interest.

Although surveys assessing STEM-related attitudes have some items on self-efficacy, they focus on self-efficacy in disciplinary STEM learning. In other words, most existing instruments measuring self-efficacy in science, mathematics, engineering, and technology have treated STEM as isolated subjects. Apart from the missing feature of STEM integration, the survey items on STEM self-efficacy have used the language of engineering, which may be unfamiliar even for students from high school (Oh, Jia, Sibuma, Lorentson, & LaBanca, 2013).

A few STEM self-efficacy surveys have adopted a perspective of integrated STEM education (Milner, Horan, & Tracey, 2014; Nugent, Barker, Grandgenett, & Adamchuk, 2010; van Aalderen Smeets, Walma Van Der Molen, & Xenidou Dervou, 2018). Nugent, Barker, Grandgenett, and Adamchuk (2010) developed a survey for students' self-efficacy in learning robotics and GPS/GIS, which, however, was limited in terms of the range of STEM activities. There are some surveys suitable for high school or college-level students, which mention some difficult practices, such as "measuring the speed of electrons" (Milner, Horan, & Tracey, 2014), or using some abstract phrases such as "skills taught in STEM classes" (van Aalderen Smeets, Walma Van Der Molen, & Xenidou Dervou, 2018). However, these surveys are not suitable for younger students.

To conclude, there is a lack of measures for students' self-efficacy in STEM activities emphasizing students' STEM practices rather than disciplinary learning in science or mathematics, especially for younger students. STEM learning is different from the traditional classroom learning of science or mathematics in that it emphasizes learning in scientific and engineering practices. Therefore, the existing surveys may not be able to deal with "hands-on" and integrated features of STEM learning experiences. To address this research gap, this study proposes to develop a survey which can better address students' self-efficacy in STEM activities.

In addition, there are a few existing measures for career-related outcome expectations (Hazari, Sonnert, Sadler, and Shanahan, 2010). Yet, there is no existing survey for STEM career-related outcome expectations in the literature. In this study "STEM outcome expectations" specifically refers to STEM career-related outcome expectations, which is the expected outcome of becoming a STEM professional.

Last but not least, a review from the existing measures for STEM career interest shows that there is no such measure suitable to assess students' general interests in STEM careers. Career interest is a widely used but not so well-defined concept in the literature on STEM education. Measurements for STEM career interest in the literature assess a spectrum of constructs including career-related attitudes towards STEM careers (Kier, Blanchard, Osborne, & Albert, 2014), intentions to enter STEM careers (Sadler, Sonnert, Hazari, & Tai, 2012), and interest in entering STEM careers (Diekman, Brown, Johnston, & Clark, 2010; Oh, Jia, Lorentson, & LaBanca, 2013).

In the measure for career interest used in Diekman, Brown, Johnston, and Clark's study (2010), there are only four items, with one item for each STEM occupation (e.g., industrial engineer), which limited the coverage of careers. Moreover, the Educational and Career Interest in STEM survey developed by Oh, Jia, Lorentson, and LaBanca (2013) also treated STEM career interest as interest in entering STEM careers, which is close to the conceptualization in this study. Nevertheless, this survey treats STEM as four disciplines with each item addressing one discipline, with the items about engineering being deleted after factor analysis.

3.2 Theoretical framework and its relation to the research gaps

Based on the research gaps, a theoretical framework was developed with reference to the existing literature. The theoretical framework, associating perceptions (including stereotypes of STEM careers) with students' learning outcomes related to career development, is shown in Figure 2.

The associations among self-efficacy, outcome expectations and STEM career interest in the theoretical framework remains consistent with the established associations among self-efficacy, outcome expectations and career interest and goals in the SCCT model. The reasons include: 1) The SCCT model has been widely accepted in career development theories; 2) the associations among the constructs have received much empirical support in science, technology, engineering and mathematics education (Lent et al., 2018; Lin & Deemer, 2019; van Tuijl & van der Molen, 2016).

Perceptions of STEM careers, including stereotypes, have been added to the theoretical framework because of the following hypothesis and conclusions from the literature review. Unlike many more socially interactive occupations (such as police officers, journalists) who spend a lot of their work time with people, STEM careers are often under-represented (Jennings, Mcintyre, and Butler, 2015) or mis-presented in mass-media and in many people's daily lives. Therefore, students have tended to lack perceptions of STEM careers or have STEM stereotypes. Also, the lack of perceptions or biased perceptions may have deterred adolescents' career development in STEM fields, according to the literature review.

The under-explored qualitative associations between students' perceptions of STEM careers and their constructions of career interest and goals, possibly via self-efficacy and outcome expectations are represented as dotted lines in Figure 2, even though the actual associations may be much more complex than a direct relation. The presentation of qualitative research gaps (shown as dotted lines in Figure 2) is only a simplified visualization for easier conceptualization.

Specifically, STEM stereotypes, as a component of perceptions of STEM careers, may have an influence on students' STEM career interest through both self-efficacy and outcome expectations. These indirect effects were also added to the theoretical framework (see Figure 2) and were explored in this study

The research gaps regarding examining students' perceptions of STEM careers and assessment of STEM career-related variables were incorporated in the theoretical framework. Though the research gap regarding assessment were not explicitly illustrated in Figure 2, it was addressed by assessment of some important STEM career-related learning outcomes (e.g. STEM self-efficacy in STEM learning, STEM career-related outcome expectations, and STEM career interest) in this study.

STEM career decisions may develop as early as childhood (van Tuijl & van der Molen, 2016). Some researchers have suggested in the period of 10 to14 years old students begin to form concepts of science-related careers (Archer et al., 2012; DeWitt, Archer, & Osborne, 2013). However, STEM stereotypes may have formed and become evident at the elementary level. Therefore, it is expected that upper elementary (4^{th} to 6^{th} grade) level could be considered an appropriate age range for the present study as the findings may serve as a baseline for future studies.

3.3 Research questions

Based on the three research gaps and theoretical framework, the research questions (RQs) are listed as follows:

RQ1: What are elementary students' perceptions (i.e., stereotypes, diversity of careers, and the content of work) of STEM careers, including scientists, engineers, and technologists?

RQ2: What role do elementary students' perceptions of STEM careers play in the negotiation incorporating STEM self-efficacy and STEM career-related outcome expectations which constructs their career interest and goals?

RQ3: What are the associations among elementary students' STEM stereotypes, STEM self-efficacy, STEM career-related outcome expectations and career interest?

RQ 3.1 Are the developed surveys for STEM self-efficacy, STEM career-related outcome expectations, and STEM career interest reliable and valid measuring tools?

RQ 3.2 What role do STEM stereotypes play on the positive effect of STEM self-efficacy and STEM career-related outcome expectations on students' STEM career interest?

RQ1 addresses the research gap in examining students' perceptions of STEM careers, especially under the case that little is known about students' perceptions of technologist as a STEM career. RQ2 and RQ3 addresses the second research gap that the association between STEM careers (including STEM stereotypes) and construction of career interest is poorly understood. RQ2 is a qualitative research question while RQ3 is a quantitative one. As quantitative studies require clearly defined variable, STEM stereotypes, rather than perceptions of STEM careers were used in this research question, because STEM stereotypes are more conceptually convergent and has been used as a psychological construct. Specifically, RQ 3.1 addressed the research gap in assessment of STEM career-related variables.

The focus of each of the research question and its relation to the overall theoretical framework is shown in Figure 3.

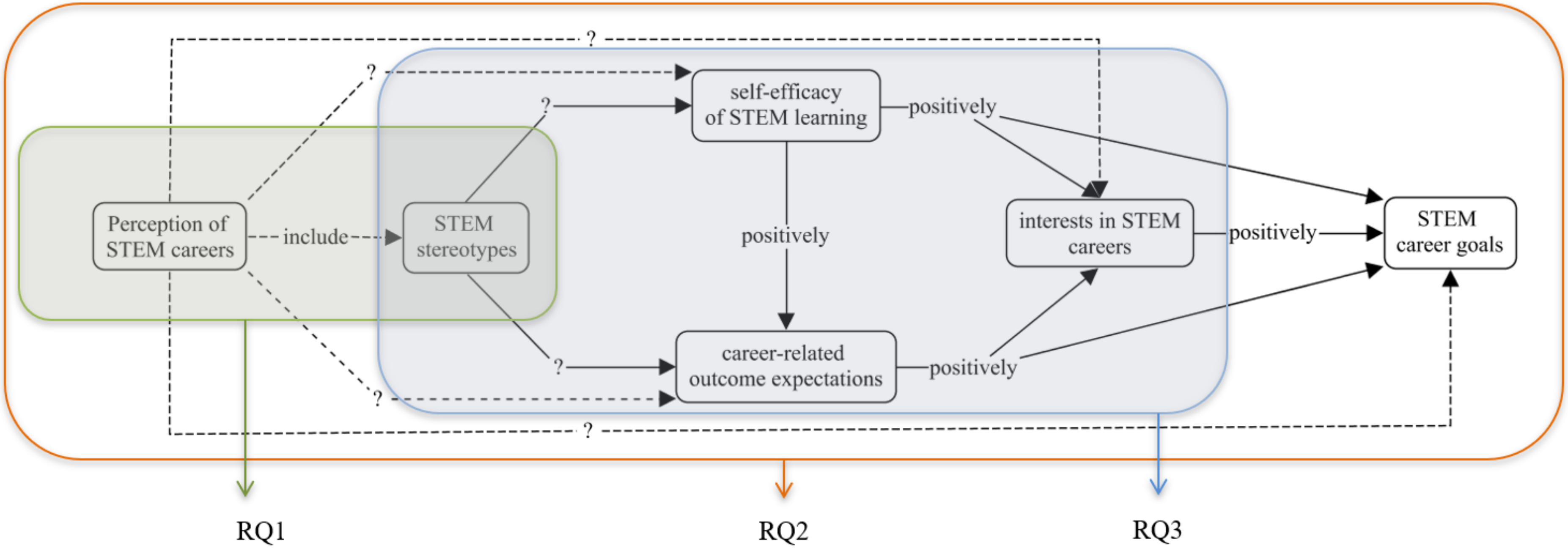


Figure 3. Theoretical framework and the focus of research questions

[The focus of the research questions is highlighted in rounded rectangles in this figure, with RQ1 in a green rounded rectangle on the left, RQ2 in an orange rounded rectangle which is the biggest, and RQ3 in an blue rounded rectangle; A line with a question mark (?) shows the research gap and associations that need to be explored in this study. A solid line (shown by ——) indicates a quantitative relation while a dotted line (shown by - - - -) indicates an expected qualitative association.]

4. Methods

The research methods consist of a qualitative survey with content analysis, semi-structural interviews with thematic analysis (TA) and structural equation modelling (SEM) analysis, which are interrelated but independent, to answer the three research questions. The relationship between research questions and the methods are shown in Table 1. Only the interviews address both RQ1 and RQ2, while other methods mainly deal with one according research question.

Table 1. Research questions and methods

	Qualitative survey and content analysis	Interview and thematic analysis	Quantitative survey and SEM
RQ1	√	√	
RQ2		√	
RQ3			√

The rationale of adopting the research methods is as follows:

RQ1 is a qualitative research question exploring students' perceptions of STEM careers in general. To answer it, qualitative methods are used including a qualitative survey and interviews. The survey has a rather large sample size and provides a big picture view depicting how upper-elementary Hong Kong students perceive STEM careers, while the semi-structured interviews show students' in-depth perceptions.

Content analysis and thematic analysis were adopted to analyze the qualitative survey data and interview data respectively.

RQ2 is a general, wide-ranging question regarding how individuals construct their career interest/goals, especially focusing on the role played by their perceptions of STEM careers. Semi-structured interview items were designed to answer this research question by gathering students' in-depth comments regarding how they construct their career interest. Thematic analysis was used to analyze the interview data.

RQ3 is quantitative in nature, exploring how an element of perceptions of STEM careers, namely STEM stereotypes, further influence other career-related constructs and have an impact on students' career interest. To answer this research question, the current research used quantitative surveys and the data were analyzed using structural equation modelling technique. First, developed or translated Likert-type surveys were validated to measure the constructs (STEM stereotypes, self-efficacy in STEM activities, STEM outcome expectations, STEM career interest). Then the quantitative association among these constructs was tested using SEM analysis.

The methods were presented in Table 2 in detail, which also shows how each the methods connect with the research questions.

Table 2. Research questions and the research methods in detail

Research questions	Methods and procedure
RQ 1：What are elementary students' perceptions (i.e., stereotypes, diversity of careers, and the content of work) of STEM careers, including scientists, engineers, and technologists?	**Qualitative survey with content analysis (n=564)** ▪ A qualitative survey was developed to examine students' perception of STEM careers (scientists, engineers, and technologists). ▪ Two checklists and a categorizing process were used to perform content analysis on the data. **Interviews and thematic analysis (n=31)** ▪ Students responded to a short survey probing their perceived careers belonging to scientists, engineers, technologists and STEM careers. ▪ Then they were interviewed to explain their options and summarize what these professionals do at work. The transcripts were analyzed through thematic analysis.
RQ 2：What role do elementary students' perceptions of STEM play in the negotiation incorporating STEM self-efficacy and STEM career-related outcome expectations which constructs their career interest and goals?	**Interview with thematic analysis (n=31)** ▪ Students were interviewed, and the transcripts were analyzed through thematic analysis.
RQ 3：What are the associations among elementary students' STEM stereotypes, STEM self-efficacy, STEM career-related outcome expectations and career interest?	**Quantitative survey with structural equation modeling (n=844)** ▪ Three surveys were developed and one survey was translated; they were Likert-type surveys validated using factor analysis. ▪ The surveys were administered to students. ▪ Structural equation modeling (SEM) was conducted to validate the surveys and test the hypothesized model.

The relationships between the qualitative survey with content analysis, interviews with thematic analysis, and quantitative survey with SEM analysis were illustrated in Figure 4. The timeline of the data collection of the three parts of the study, namely the qualitative survey collection (n=564), conducting the interviews (n=31), and quantitative survey collection (n=844) was also shown in Figure 4. It should be noted that all elementary schools in Hong Kong have received yearly government funding for STEM curriculum since 2016 and the schools participated in this study (school A-G) have all initiated STEM courses to their 4th-6th grade students, according to the teachers contacted from each school.

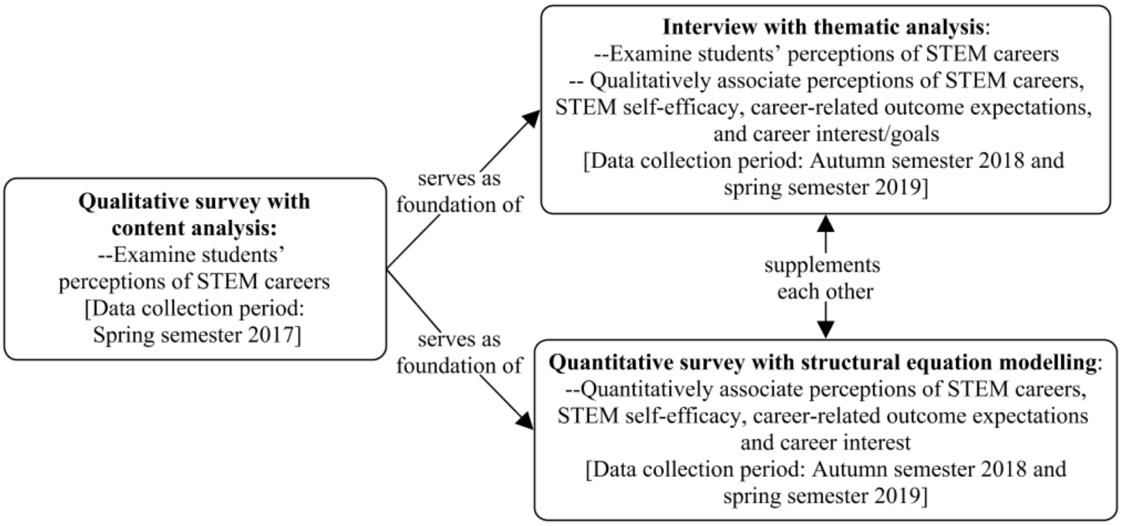


Figure 4. The relationships among the different parts of the study and timeline of data collection period

The qualitative surveys collected could serve as foundations for interviews and SEM analysis as it provides answers to the question about what students' perceptions of STEM careers are. Specifically, the findings from the qualitative survey with content analysis may facilitate the design of the interview protocol and development of STEM stereotypes survey used in the quantitative survey with SEM analysis.

Convergent model of triangulation design in mixed-method research (Creswell & Clark, 2000) was adopted to explain how two parts of the study, namely interviews with thematic analysis and the quantitative survey with SEM worked together.

Specifically, parallel-databases variant of convergent design was used since the interview data and quantitative survey data were analyzed relatively independently and were only compared in interpretation. The intent of using both these two types of data is to collect “different but complementary data on the same topic” (Morse, 1991, p. 122).

Both the interviews with thematic analysis and the quantitative survey with SEM analysis address the aim of exploring the role of perceptions of STEM careers in construction of career interest/goals from a qualitative and quantitative perspective respectively. The mixed-method approach could compensate the weaknesses of using qualitative or quantitative method alone, and thus the results from interviews with thematic analysis and quantitative survey with SEM could supplement each other. For example, STEM stereotypes may not be efficiently covered in the interviews as students may have such perceptions more implicitly than other explicit attitudes/perceptions. However, STEM stereotypes could be measured by surveys in the SEM study.

4.1 Qualitative survey and content analysis

The qualitative surveys (with drawing tasks and follow-up questions) collected were analyzed with content analysis. This section introduces survey instrument development, sample, and data analysis methods using content analysis, which include analysis using two developed checklists and a categorizing process.

A definition of technologists was summarized with reference to the Occupational Information Network (O*net), an up-to-date online database containing career definitions and information, which is an outcome of a large-scale study (National Research Council, 2010). The definitions and information of 40 occupations related to technologist/ technician were extracted from O*net before being coded to extract the keywords. The definition of technologist used in this study was then summarized as follows:

"Technologists are people who work with (e.g., operate, adjust,) specific technological products and/or perform technological processes (e.g., testing, analysing) to achieve a goal that is beneficial to society (e.g., maintaining a system, producing a product), usually by assisting STEM professionals (e.g., engineers or scientists). In addition, technologists apply disciplines of science/ engineering/ mathematics in their work."

4.1.1 Instrument development for writing and drawing tasks

The instrument used was developed with reference to those used in the study of Farland-Smith & Tiarani (2016) and involved several rounds of discussion and revisions. In the revision, the researcher of the current study also made reference to the DAST and its later versions including Draw-A-Scientist-At-Work Test developed by Flick (1990) and the Draw-An-Engineer-At-Work Task developed by Fralick, Kearn, Thompson, and Lyons (2009).

Farland-Smith and Tiarani (2016)'s instrument was chosen for revision in this study because it focuses more on the drawn STEM professionals' work and also the drawing tasks were combined with follow-up questions. The combination of drawing together with written responses is based upon the consideration that a drawing task of a STEM professional at work is age-appropriate for fourth to sixth graders, and the follow-up questions can make interpreting drawings less ambiguous while providing deeper information, addressing the concern raised by Bielenberg (1997) that interpreting drawing tasks alone may be misleading.

The instrument comprised three parts; each began with a drawing task with the prompt "draw a/an … (STEM professional) at work" task (here "STEM professional" refers to scientists, engineers and technologists) and open-ended questions about the drawn scientists, engineers and technologists, including what the STEM professional is doing in the drawing and what the most important task in the drawn STEM professional's work is. The first question probed the students' interpretation of their own drawing of the STEM professional's work and the second question asked students to think about what the most important part of the STEM professional's work is.

Three words of "scientists", "engineers" and "technologists" rather than the phrase "STEM professionals" was adopted in the survey because according to informal discussions with students, students were less familiar with the concept of STEM careers/professionals, but they could talk more about scientists or engineers. As qualitative surveys require more in-depth information than quantitative surveys, it would be more appropriate to use words that students were more familiar with to probe their perceptions. Besides, to make better-informed career decisions in the future, students need to know that scientists, engineers, and, technologists are related but different careers.

In addition, scientists, engineers, and technologists were included in the questionnaire as examples of STEM professionals because: 1) due to the limited time allowed for students' completion and limited attention span of students, the survey length should be short; 2) scientists, engineers, and technologists cover a large percentage of STEM careers and 3) these three STEM professions use science, technology, engineering and mathematics in their work.

The draft instrument was reviewed by four experts in science education, including two researchers in STEM education and two Ph.D. graduates in science education). The gathered suggestions for revision were carefully examined before some were adopted. An elementary school teacher also reviewed the instrument to check and make sure the items were understandable for 4^{th} to 6^{th} grade students. Then the instrument was piloted on nine students (six fifth graders and three sixth graders) from a public elementary school to ensure upper-elementary students could understand the wording of the instrument and give valid answers. The pilot test showed that the instrument was easily understood.

4.1.2 Sample

Consent forms and information sheets were issued to students and parents and when consent was received from the students and parents, the students' teachers administered the anonymous survey to their students in their classrooms. Data were not collected from students who decided to withdraw from the study during or after collecting the consent forms.

As shown in Table 3, among the valid sample (n=564), there were two groups of 4th to 6th grade elementary students in Hong Kong. The first group was 260 4th to 6th-grade students from intact classes in three public elementary schools (School A, B and C) and the second group comprised 304 4th to 6th-grade students who were participants in an annual STEM event. The sampling strategy ensured that the data could be collected from a variety of students who had a variety of STEM learning experiences. The three schools, each from different districts in Hong Kong, are all government-aided schools, which is the school type that covers 81% of elementary schools in Hong Kong. Elementary schools in Hong Kong do not use banding based on students' performance. Generally, students from government-aided schools are mostly from middle-level socioeconomic families in Hong Kong. The three schools are co-ed schools, similar to 94% of all elementary schools in Hong Kong.

Table 3. Demographics and background of the qualitative survey sample

		Number	Percentage in valid sample (%)
Group	Non-STEM-event participants	304	53.9%
	STEM-event participants	260	46.1%
grade	4	156	27.8%
	5	257	45.8%
	6	148	26.4%
gender	Boy	326	58.6%
	Girl	230	41.4%
Total		564	100.0%

The instrument and the students' responses were written in Chinese. The data collected contained no identifiable information about participating students. There were 564 valid surveys collected, with 40.8% from girls and 57.8% from boys. The students were from grades four (27.8%), five (45.8%) and six (26.4%). A review of the previous literature examining perceptions of STEM careers using a similar qualitative methodology indicates that the sample size here was adequate (Finson, Beaver & Cramond 1995; Subramaniam, Esprívalo, Harrell & Wojnowski, 2013). To explore the proportion of participants who knew STEM professionals personally in their lives, items were included asking whether students knew scientists/ engineers/ technologists. According to the valid responses, 4.1%, 18.3% and 7.3% participating students indicated that they knew at least one scientist, engineer or technologist respectively in their lives (as parents/ relatives/neighbours etc.).

4.1.3 Data analysis

Drawing data were scanned and students' written responses were input using Excel. To analyze students' perceptions of scientists, engineers, and technologists, three part of content analysis were conducted, including coding using two checklists and a categorizing process.

To capture the emergent features in students' drawings and written descriptions of the STEM professionals at work, two checklists were developed and used respectively. Checklists can help to calculate the frequencies of emergent features in students' drawings and written responses. "Listing frequencies can also help in identifying prominent themes" (Johnson & Christensen, 2008). In previous studies, many researchers have used the checklist developed by Finson et al. (1995) named Draw-A-Scientist Test Checklist (DAST-C) to analyze students' drawings through which features within could be numerated and then analyzed statistically. However, as the widely used DAST-C was not designed for drawings of engineers or technologists, two new checklists were developed in this study. Inter-rater reliabilities were calculated for the coding using the checklists.

Analysis 1: Checklist development for the work of STEM professionals

A checklist of the STEM professionals' work in students' descriptions of their drawings was developed to analyze students' responses. The analyzed content was students' written responses to what the drawn STEM professional was doing (in the drawing) and what the most important task in the drawing was. Firstly, the researcher of this study generated an initial list for the checklist after reviewing hundreds of students' responses. Then the researcher simplified the list and combined some items in the checklist until they reached the minimum number for all the features in the students' responses to be identified. After a pilot training session, about 30% of the responses were coded by both the researcher and a trained coder. The inter-rater reliability (IRR) was checked using the following formula:

IRR= (1- differently coded items/total number of items coded) *100%

The final checklist has 22 criteria. Initially, there were two criteria in the checklist with IRR lower than 80% and the two criteria were thus recoded independently by the two coders. Before recoding, the two coders shared their views regarding how they coded the drawings and discussed the discrepancies. After this recoding, the final IRR for each criterion for the coding of the drawn scientist/engineers/technologists respectively were calculated and the results ranged from 85 % to 100%. Since the coding process was trustworthy, according to the threshold of IRR (80%) suggested by Smagorinsky (2008), and the remaining drawings were coded only by the trained coder.

Analysis 2: Checklist development for the drawings of STEM professionals at work

To conduct content analysis on the drawing data and extract features from students' drawings of the STEM professionals at work, another checklist was developed. Firstly, the researcher browsed 150 students' drawings (three drawings per student) and wrote down the emergent features from the drawings to develop an initial checklist. After a training session, another coder did the same for another 150 students' drawings independently. Then the features identified by the researcher and the coder were combined to form a checklist. The items in this checklist were classified into clothing, objects, emotions and others. Afterwards, the drawings were all coded by the coder who helped in developing the checklist using the checklist. Throughout the coding process, the coder also added newly emergent items to the checklist. In this way, it was expected that the identifiable features of the drawings could be completely covered.

Approximately 27% of the drawings were coded by another coder trained by the researcher after some pilot practice. For each of the 39 criteria, IRR were checked in coding of the drawing of scientist/engineers/technologists respectively. This criterion-specific IRR ranged from 86% to 100%. According to the IRR for each criterion and the checklist, it can be assumed that the coding process was reliable. The remaining drawings were coded solely by the coder involved in the checklist development.

Analysis 3: Categorizing the students' presentations of STEM professionals

Students' presentations (here, presentations mean both drawings and writings combined) of STEM professionals were categorized into a series of career categories. The summarized categories (including the content of the work) were the results of both the summary of the students' presentations and correspondence to professions in real life. An initial review of the students' drawings and written responses altogether indicated that the students' presentations of scientists, engineers, and technologists could be categorized into a few different career categories. The researcher categorized the drawings and the students' own descriptions of the drawings. The categorizing in turn helped to revise the categories. During the categorization, as suggested by Stemler (2001), all categories were mutually exclusive and exhaustive. This process was iterative and finally 30% of the data was categorized by the researcher; meanwhile, this 30% of data was also categorized by a trained coder after a pilot categorizing practice. The IRR of the two coders was 87% and thus the categorizing process was then continued by the trained coder alone.

To conclude, the data in the qualitative survey went through coding using two checklist and a categorizing process. An example of the coding is shown in appendix 4.

4.2 Interview and thematic analysis

The students were interviewed to gather their own explanations regarding how they developed interest in STEM careers or rejected STEM careers as an aspired choice. The aim was to reveal how students themselves explain their career goals/tendencies with a focus on revealing the role of stereotypes/ misunderstandings of STEM careers in forming their construction of such goals/tendencies. In other words, the researcher was interested in how students justify their dispositions regarding their desired career interest. Since career development is a very personalized topic, the interviews were semi-structured in nature to allow room for spontaneous and case-by-case responses. And thematic analysis was applied to analyze the interview data.

4.2.1 Pilot of the interview

To gather more information regarding the suitable age range for the interviews and whether the questions were understandable, four students from school C were invited to a group interview, with two students from 4th grade, one student from 5th grade and one student from 6th grade. According to the analysis of the pilot interview, 5th and 6th grade students were found to be able to answer the questions with satisfactory length and detail while the 4th grade students might not. The researcher also decided that individual interviews would be more appropriate for the research questions because responses from one student in a group interview tended to influence other students' answers.

In addition, after reviewing the recording of the pilot interviews, the protocol was revised and expanded. As one of the students from the pilot interview mentioned some aspects of interest for the research question, the student (Frank) was also included in formal individual interviews.

4.2.2 Development of the interview protocol

The interview protocol (Appendix 4) was developed based on the theoretical framework as presented in Chapter 2. After the pilot interviews, individual interviews and the questions were re-organized to better probe students' responses. The revised interview protocol was then reviewed by a university researcher in STEM education to check the validity of questions and appropriateness of procedures. The protocol was then revised and applied in the individual interviews. After each individual interview, the interview protocol was sometimes revised based on the memo written about the reflective notes on the procedures or interview questions.

Design of the interview protocol

Although the interviews focused on the impact of perceptions of STEM careers on students' career development, the interviews began by probing students' career interest/goals. Here, the career interest/goals covered in the interviews not only included goals and interest, but also non-interest, decrease of interest, or even rejection. And students were then asked to justify and explain their career orientations or change of career orientations, especially about STEM careers. This retrospective logic and rationale (asking students to think about their career interest/goals and then asking them to justify them by reflecting on their experiences, attitudes and perceptions) lowered the cognitive burden for upper elementary students.

In case explicit associations were not evident in students' responses, some questions regarding students' STEM learning experiences, their career-related outcome expectations, and perceptions of STEM careers were also covered to provide more information. These questions were asked later in the interviews because if they were asked first, the answers would alter students' later responses about their career orientation. Since it is hypothesized that perceptions of STEM careers, outcome expectations and experiences do influence students' career orientations, the interview procedure itself needed to preclude this influence due to sequence of questions. Therefore, it seemed more appropriate that these "impact" factors (e.g., perceptions of STEM careers) were examined (asked) later than the "outcome" factors (e.g., outcome expectations, career orientations etc.) in the interview protocol.

Like the qualitative interview investigation, scientists, engineers, and technologists as STEM careers were examined in this study because these concepts are familiar to students. Some questions about "STEM careers" (or STEM-related jobs, STEM professionals) were also asked in the interviews, which could help reveal the difference between students' perceptions of "STEM careers" and "scientists, engineers, and technologists."

Procedures of the interview protocol

As for the detailed procedures of the interview, after a brief introduction to the interviewers, the purpose of the interview, and some clarifications, a short questionnaire (questionnaire A in Appendix 2) was issued to each student to collect their demographic information (grade, class, age etc.) and the student's career goals/aspirations. The interviewed student was then asked to write down the occupations they aspired to when they grow up. The questionnaire was used here because it would give the student a short period of time to calm down, carefully reflect and provide their conclusions. Upon finishing, the interviewer would ask whether the student had some more occupations to supplement, in case the student suddenly had more ideas or some unwritten answers.

Then students were asked to explain why they were interested in these careers. Afterwards, the interviewer continued with some questions in a retrospective way, mostly asking students to explain their career orientations, trying to gradually understand how students develop or construct their career goals and interest, especially about their career orientation in STEM fields. The questions tried to encourage students to explicitly elaborate on their experiences, perceptions and attitudes before forming their career orientation. Afterwards, students were asked whether they had considered scientists/ engineers/ technologists, and STEM careers as future career paths. Then they were asked to explain these career orientations in a similar way as mentioned above.

Afterwards, students were asked about their STEM learning experiences, positive and negative outcome expectations of STEM careers, and perceptions of STEM careers. As perceptions of STEM careers was the focus of the research question, another questionnaire was used (Questionnaire B in Appendix 2) to probe students' perceptions of scientists, engineers, technologists and STEM professionals. In the questionnaire, students were asked to select who belongs to each of the three career types, and STEM careers from the following occupations: 1) Researchers; 2) Inventors; 3) Construction workers; 4) Building designers; 5) Construction site coordinators; 6) Technicians (doing installation, repairing etc.); and 7) Programmers.

The seven careers in Questionnaire B were the seven categories of careers in students' presentations of scientists, engineers and technologists identified in the qualitative survey part of the study. Adding Questionnaire B in the interview was also to provide support to what categories of careers would be included in students' perceptions of scientists, engineers and technologists as established in the survey and to explore students interpretation of STEM-related jobs, a concept the researcher consistently used in the quantitative survey using structural equation modeling (discussed later in this chapter).

Students were told that they would be free to select one or more options among the careers for each item in Questionnaire B. And each option could be used multiple times. Afterwards, students were asked to provide explanations and justifications for their choices and to summarize what scientists, engineers, technologists, and STEM professionals usually do in their work.

4.2.3 Sample

Among the schools that showed willingness to participate in this study, only three schools (schools C, D, E in Table 4) agreed to invite their students to participate in the interviews. And each school agreed to arrange only a very limited number of sessions for interviews. Though school D is all-male school, which was not ideal regarding gender balance, the students were also included in the interview sample because of the limited number of interviews that could be conducted in school C and E.

The three schools (C, D, and E) were in three different districts in Hong Kong. All three schools are subsidized by the government and the instruction language is Chinese (mostly in Cantonese with a small amount of Mandarin).

- School C is a tuition-free school run by a social service organization in Hong Kong.
- School D is run by a Christian organization. It recruits students mostly from socially privileged families.
- School E is a tuition-free school run by a Christian organization.

In total, 28 students (5-6 grade) participated in the individual interviews. Students were selected randomly by their teachers and were asked whether they would like to join an interview session. According to the responses to Questionnaire A, students with STEM-related career aspirations and without STEM related career aspirations were all included in the sample. The background information of the interviewed students is in Table 4.

Table 4. Demographics of the interview sample[1]

Pseudonym	age	grade	gender	school
Peter	9	4	boy	C
Frank	11	6	boy	C
Cora	9	4	girl	C
Zoe	10	5	girl	C
Christy	10	5	girl	C
Jacky	10	5	boy	C
Celia	10	5	girl	C
Rachel	11	6	girl	C
William	11	6	boy	C
Neil	11	6	boy	C
Ann	10	5	girl	C
Phillip	10	5	boy	C
Eric	10	5	boy	C
Elizabeth	11	6	girl	C
Sandy	11	6	girl	C
Francis	11	5	boy	D
Sam	11	6	boy	D
George	10	5	boy	D
Dean	10	5	boy	D
Keven	10	5	boy	D
Carl	11	6	boy	D
Benjamin	12	6	boy	D
Jane	10	5	girl	E
Robert	13	6	boy	E
Nancy	11	6	girl	E
Paul	10	5	boy	E
Michelle	11	6	girl	E
Francis	11	6	boy	E
Lisa	10	5	girl	E
Alan	10	5	boy	E
Leo	10	5	boy	E

[1] Among these students, Peter, Cora and Zoe only participated in the pilot interview who also completed the surveys and the survey data were included in the data analysis.

4.2.4 Data collection

Individual semi-structured interviews (n=28) were conducted in a quiet classroom or conference room at the schools by the researcher with the help of a student helper who is a Cantonese native speaker. Although the researcher is fluent in Cantonese and very familiar with the topics in the interviews, a student helper was hired for each interview to avoid miscommunication between the researcher and the interviewee. The student helper helped in translation and explanations. Before the interviews, the student helper was informed about the research purpose, research questions, the interview protocol, background information about the school, and the responsibility in assisting the interview process. For most of the time the interviews involved only the researcher and the participants. Each student's interview time ranges from 16 to 25 minutes.

4.2.5 Interview data analysis

The interviews were audiotaped and transcribed verbatim by trained Cantonese-native-speaking student helpers. The transcriptions were double-checked by the researcher to ensure the accuracy of transcription. The responses in the questionnaires were also input into an Excel file for analysis using descriptive statistics. Pseudonyms were used for each case and identifiable information of the students was anonymized in the transcription data.

As recommended by Johnson and Christensen (2008), during the interviews, memos were written by the researcher (also the interviewer) to record reflective thoughts regarding the participants, the hypothetic codes or the interview process. A summary for each interview was also written by the researcher to keep a record of the summarized themes in the students' responses and features identified in the interviewed student. For each interview (or each student), the memo written by the researcher, the interview transcript, the students' response to Questionnaires A and B, and the summary were combined into one folder (or case) in Nvivo software for analysis.

The researcher analyzed the interview transcripts using thematic analysis (TA) under the guidelines of Braun and Clarke (2006). This method was adopted because after familiarization with the interview data, the researcher believed that to answer the research question, TA was the best fit for uncovering the processes or associations in students' minds

The transcribed interviews were coded using NVivo software. A coding scheme was developed with priori codes combined with inductively emergent codes, which means both preexisting and inductive codes were used in the coding process. The coding scheme was revised and supplemented during the process of coding. Students' perceived associations among their perceptions of STEM careers, students' STEM self-efficacy, students' career interest and goals were examined. Face validity and content validity of the coding scheme were evaluated by a professor in STEM education with expertise in qualitative studies. Apart from the expert review, the coding scheme was continuously revised, with codes emerging and combined during the whole coding process. The key codes and themes in the coding scheme were shown in appendix 8.

Performing this first stage of coding enables researchers to dissect the data (Strauss & Corbin, 1990) and capture as much meaning as possible. At this early stage, the coding involves extracting the meaningful elements that are related to the research question. For example, in students' responses, different aspects of the outcome expectations of becoming a scientist may be mentioned. These different aspects were identified using different codes under the code of outcome expectations.

The second stage is to code the "association among the constructs", which usually resulted in coding a subtheme or a theme. In most cases, the identified associations were from students' own narrated attribution. For example, a student may attribute their interest in becoming a scientist to having high grades in science. The association between "career goal as a scientist" and "having high self-efficacy in science achievement" were thus identified and coded. Afterwards, the associations went through a process of constant comparison with one another until some initial subthemes and themes were formed to describe the association. The subthemes and themes continued to emerge during the coding process, and some were collapsed into each other or modified.

For better clarification, an example of coding was provided below, the excerpt was selected from transcript of an interview with Jane (fifth-grade girl):

Interviewer: *Well then, have you thought about becoming an engineer?*

Jane: *Could be very tiring or get sunburnt.*

Interviewer*: Why would you think it could be tiring or you could get sunburnt?*

Jane*: Because usually, things like to build some buildings would make (people) feel very heavy or something like that.*

In this quote, Jane mentioned three main aspects that are significant in the construction of her career interest. Firstly, she expressed her uninterest in becoming an engineer by her negative response. In that negative response, she anticipated being "tiring or get sunburnt" if she became an engineer. She further explained this expectation and relating it to engineers' task of building. Therefore, three codes were used first, namely "reject engineers", "discomfort", and "task of engineers-building".

Some parent codes of the three codes were also coded, including "CI" (i.e. career interest), which is the parent code of "reject engineers", "negative OE" (i.e. negative outcome expectations) which is the parent code of "discomfort", and "P" (i.e. perceptions). Moreover, these codes were connected in the quote. The student attributed her being uninterested in engineers to the expected outcome of feeling discomfort and she associated these outcome expectations with her assumed task of engineers (building). Based on these codes and connections, a subtheme has emerged, namely "Task of engineers (building) → Negative OE (discomfort/ dangerous)→ reject engineers", in which the → showed the possible. This subtheme showed how the student associated these constructs and form her career orientation. Through comparison with many other quotes, a more abstract theme named "P→OE→CI" was also used to code the association among perceptions of STEM careers, outcome expectations and career interest shown in this quote. More detailed information about the codes and themes and examples of coding are shown in appendix 8.

Holland & Quinn (1987) argued that some values shared by interviewers and interviewees are assumed and therefore are taken for granted. Thus, these unmentioned shared assumptions were also identified in the analysis. As suggested by Braun and Clarke (2006), memos were written during the coding process to keep track of the code development and reflections of the coding process.

4.3 Quantitative survey and SEM

To answer RQ3, the four constructs (students' STEM stereotypes, STEM self-efficacy, outcome expectations and career interest) were measured using Likert-type surveys and the associations among these constructs were explored using Structural Equation Modelling (SEM) technique. First, surveys for these four constructs were either translated or newly developed. Second, the surveys were validated through steps including expert review, student interview, piloting, Exploratory Factor analysis (EFA), and Confirmatory Factor Analysis (CFA). Afterwards, the seven hypothesized models depicting the associations among the constructs were tested and compared using SEM.

Consistent with the perspective of integrated STEM learning of this study, the measure of students' STEM self-efficacy focused on students' self-efficacy in STEM activities. STEM activities in this study refer to learning activities in which science, technology, engineering, and mathematics learning happens in scientific inquiry or engineering design process, consistent with the practices in a STEM professional's everyday work. For example, in STEM activities, such as the scientific inquiry process, problem-based learning, or project-based learning, students may engage in activities that urge them to apply their knowledge in mathematics and science in inquiry, design circle or problem-solving processes. The other three key constructs, namely STEM stereotypes, outcome expectations and career interest are concepts closely related to STEM careers. STEM careers were used as a concept in these measures. STEM careers in this study and in these surveys refer to careers that use science, technology, engineering and mathematics in an integrated way. For example, scientists, engineers, and technologists are typical STEM careers.

4.3.1 The hypothesized models

Seven hypothesized models are proposed in this study (Figure 5) to describe the quantitative association among students' prevalent stereotypes in STEM careers and how they influence students' career interest through self-efficacy and outcome expectations.

The associations among self-efficacy, outcome expectations and career interest are consistent with the SCCT model and many empirical studies (Lent et al., 2015, 2018) in all the proposed hypothesized models. Since certain qualitative investigations provide empirical support for the direct effect of STEM stereotypes on career interest, this effect was also examined in some of the proposed models (model A, B, C and G). In addition, based on theoretical evidence and empirical findings covered in the literature review, the indirect effect of STEM stereotypes on career interest through self-efficacy and outcome expectations are newly included in some of the proposed models. These three paths are all included in the first hypothesized model (model A in Figure 5), whereby STEM career interest is directly predicted by STEM stereotypes and indirectly predicted by STEM stereotypes through self-efficacy in STEM activities and STEM outcome expectations.

As the direct effect of STEM stereotypes on career interest and the indirect effects of STEM stereotypes on career interest via self-efficacy and outcome expectations do not have abundant support in the literature, six more models have been proposed in this study, each supporting one or two of these three effects. The models (B-G) are shown in Figure 5.

In model B, STEM stereotypes directly predict career interest and indirectly predict career interest via self-efficacy, and in model C, STEM stereotypes directly predict career interest and indirectly predict career interest via outcome expectations. Model G includes the direct effect (STEM stereotypes →career interest) only. In model D, E, and F, STEM stereotypes only indirectly predict STEM career interest. In model D, the indirect effects of STEM stereotypes on career interest are both through self-efficacy and outcome expectations. In model E, the indirect effect is only via STEM self-efficacy. And in model F, STEM stereotypes have only an indirect effect via outcome expectations.

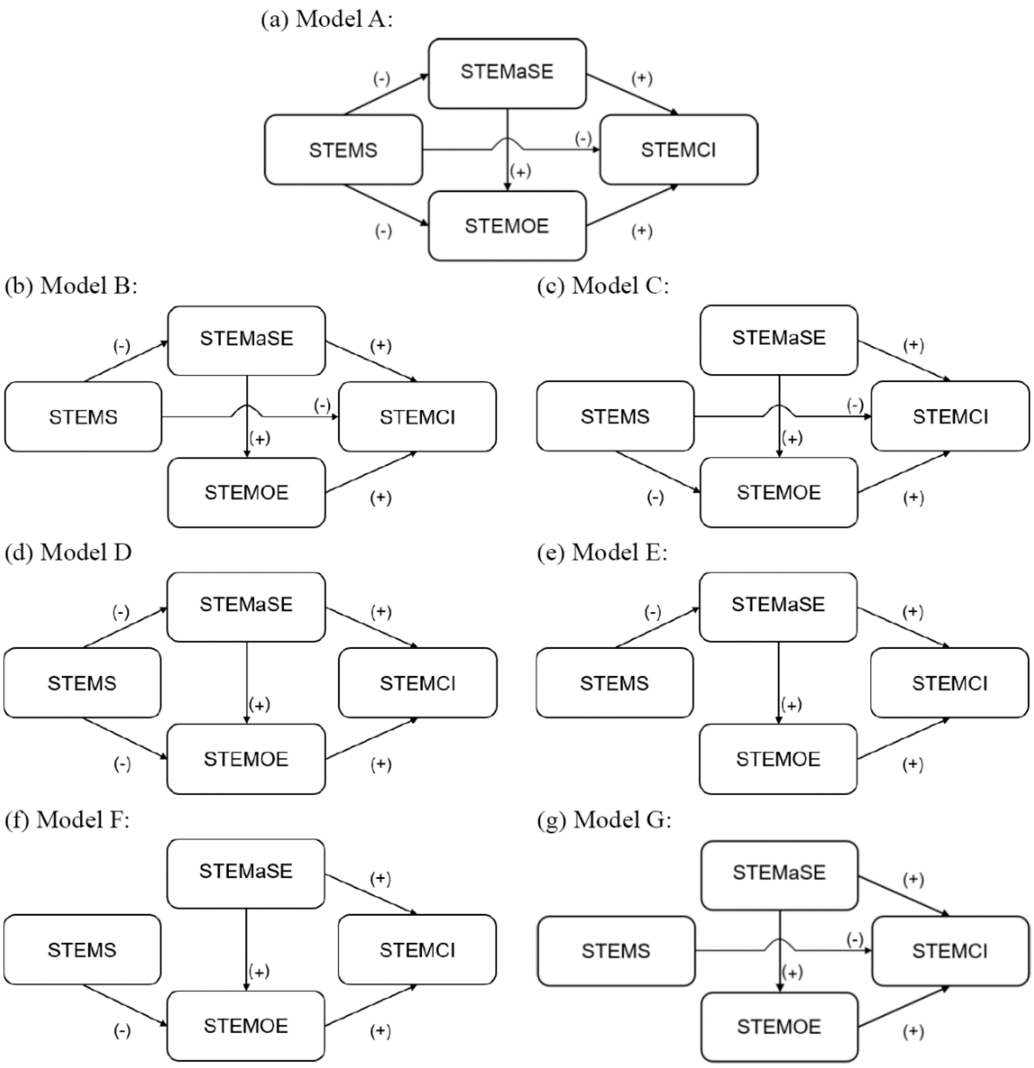


Figure 5. The hypothesized models

("+" on the arrow shows a positive effect, while "-" shows a negative effect; STEMS refers to STEM stereotypes; STEMaSE refers to self-efficacy in STEM activities; STEMOE refers to STEM outcome expectations; STEMCI refers to STEM career interest)

4.3.2 Item pool development for the surveys

The surveys were developed, translated or/and revised to measure STEM stereotypes, STEM self-efficacy, STEM career-related outcome expectations and career interest. In this part of the study, the measure for STEM stereotypes was translated and slightly modified from the Math and Science Stigma Scale (MASS) (Garriott et al. 2016). And the surveys of self-efficacy in STEM activities (STEMaSE), STEM career-related outcome expectations (STEMOE), and STEM career interest (STEMCI) were newly developed (details are shown in Table 5).

Table 5. Variables and surveys in the SEM analysis

Variable measured	Survey	description
STEM stereotypes	MASS	Translated and revised from Math and Science Stigma Scale (MASS) developed by Garriott et al., (2016)，with two self-developed items.
Self-efficacy in STEM activities	STEMaSE	Self-developed survey based on the framework developed by So, Zhan, Chow, & Leung (2017)
Career-related outcome expectations of STEM	STEMOE	Self-developed survey
STEM career interest	STEMCI	Self-developed survey

Survey 1: STEM stereotypes

The measure for STEM stereotypes, namely MASS developed by Garriott et al. (2016), was translated by the researcher, who is a Chinese native speaker, fluent in English, and familiar with the topic. MASS was translated and was slightly revised for better comprehension by fourth- to sixth-grade students. The translation was then examined by a professional in STEM education who is a native Chinese speaker and fluent in English. Then the Chinese version was back-translated into English by a Chinese-native speaking graduate who majored in English. Afterwards, the translated items were compared with the original items by a Ph.D. student in science who is an English native speaker. According to the comparison, the translation deemed to be accurate. Two items were added to the survey on STEM stereotypes, based on results from the qualitative survey. The two items are “People doing STEM-related jobs always do physical labor” and “people doing STEM-related jobs need to move heavy things, fix and build”.

Survey 2: STEM self-efficacy in STEM activities (STEMaSE)

A measure for self-efficacy in STEM activities (STEMaSE) has been newly developed. The item pool of STEMaSE was developed based upon the framework developed by So, Zhan, Chow, & Leung (2017). The framework helps to analyze upper-elementary students’ practices in science, technology, engineering, and mathematics, i.e., the learning that happens in STEM project-based activities (So, Zhan, Chow, & Leung, 2017), which meets the aim of the STEMaSE measure well. This framework, developed based on literature review of STEM curriculum standards and reports, has been applied to an analysis of students’ learning experiences in 30 project reports of STEM activities (So, Zhan, Chow, & Leung, 2017).

The practices that are believed to be most important in STEM learning were selected from the practices identified in the framework developed by So et al. (2017) as reference for the survey items of STEMaSE. The selected phrases of the practices each (e.g. “Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success”) were then modified to express students’ self-efficacy in these practices (e.g. “I am able to test and compare different solutions”). In the designing of the survey, self-efficacy in STEM activities is not confined to students’ learning in STEM courses. The items are about the practices that also happens in STEM professionals’ everyday work. Therefore, they are also career activities.

In the current study, the item pool of the STEMaSE measure in the current study was then reviewed by two researchers with expertise in science education and items were selected to form the initial survey. According to the items, higher scores in the STEMaSE survey indicated higher perceived capability to perform STEM practices in inquiry or problem-solving processes (including practices like designing inquiry processes, design solutions to problems, and analyzing data etc.).

These practices are closely related as components of coherent STEM activities. A review of previous measuring tools indicated that self-efficacy in STEM may exhibit a one-factor structure when STEM practices was emphasized in the items (Milner, Horan, & Tracey, 2014), which was also emphasized in the STEMaSE in this study. STEM self-efficacy measures may also have a multi-factor structure, when every item has a domain focus, namely, not all items covers all STEM domains. For example, measures for attitudes towards STEM with a certain degree of integrated STEM perspective exhibited a three-factor structure as S-T-M (Oh et al., 2013) or S-TE-M (Unfried et al., 2015).Therefore, the STEMaSE survey is expected to be either single-factor as the items could be viewed as very closely related components of a whole STEM activity continuum or three-factor as it could also be viewed with domain focus including science, mathematics, and engineering/technology practices.

Survey 3: STEM outcome expectations (STEMOE)

In this study, the STEMOE survey was newly developed, focusing on social career-related outcome expectations (e.g., "If I do STEM-related jobs, I can help others"). According to Bandura (1986) outcome expectations include three types, including social outcomes, physical outcomes and self outcomes. The STEMOE survey used in this study was developed based on a literature review, the researcher's experiences, and discussions with upper elementary students. Afterwards, the items from the item pool were selected by two other researchers in science education for later expert review.

Survey 4: STEM career interest (STSEMCI)

To assess students' interests in choosing STEM careers, a new survey was developed as part of the present study. The item pool was based on a review of other instruments in literature and informal discussions with upper elementary students. Five items were selected by two other researchers in science education.

4.3.3 Expert review

The translated and revised survey (MASS) and the items selected from the item pool were then reviewed by three researchers in STEM education. The three researchers included two researchers in STEM education working in a university and a mathematics education Ph.D. student with three years of teaching experience in elementary science, mathematics and computers. The expert review was conducted either in paper-based format or combined with face-to-face interviews. In the paper-based format, the definitions of the measured constructs were given and the reviewers were asked to evaluate whether the items targeted the construct and whether the items were well understood by upper elementary students. The reviewers were also asked to give comments on the items. The expert review process helped to identify items with lower validity which were deleted or revised.

4.3.4 Student interviews

Two groups of Hong Kong students (5^{th} and 6^{th} graders) were invited to group interviews for further validation of the wording of the surveys. Upon completing the surveys, students were asked to share their confusions about item wording if any. Afterwards, the interviewer read aloud each item and asked whether all students could fully understand it. If students indicated confusion over an expression, the interviewer would explain it and ask the students if they could provide alternative expressions with similar meanings which they could easily understand. Then some wordings were revised.

4.3.5 Pilot test

Students (grade 4-6) participating in a STEM fair were invited to participate in the pilot test of the surveys because they were within the same age range as the target group and they had experience in integrated STEM activities. Invitations to participate in the survey were sent to students enabling them to voluntarily participate in this part of the study after the STEM fair. One hundred and eleven copies of paper-based surveys were collected. As indicated by indices such as item-total correlations, no items were deleted at this stage; Cronbach's alphas of the surveys were satisfactory as shown in Table 6.

Table 6. Cronbach's alphas of surveys in the pilot test

Measured variable	Survey	Item number	Cronbach's alpha
STEM stereotypes	MASS	10	0.889
Self-efficacy in STEM activities	STEMaSE	12	0.897
STEM Outcome expectations	STEMOE	5	0.803
STEM career interest	STEMCI	5	0.892

4.3.6 Sample

The sample for the formal test was conducted on fourth to sixth grade students from four government-aided elementary schools in four districts in Hong Kong. Consent was attained from students and their parents and then students completed the paper-based anonymous surveys. The survey was administered under the guidance of teachers in students' classrooms. The return rate of the questionnaire was 93%. The demographic summary of the sample (n=844) is shown in Table 7. School D, whose students participated in the interview study, were not included in the sample here because school D is all-male. School F and G were also invited to participate in the student interviews; however, they declined and were willing to participate only in the quantitative survey. Therefore, these two schools were included in the sample for the quantitative survey and not in the interviews.

Table 7. Demographics of the SEM analysis sample

		Participants	Percentage in valid sample (%)
School (valid)	School C	152	18.0
	School E	215	25.5
	School F	168	19.9
	School G	309	36.6
Grade (valid)	4th	254	30.9
	5th	296	36.0
	6th	272	33.1
Gender (valid)	Male	410	50.0
	Female	410	50.0
Total		844	100

4.3.7 Data analysis

The survey data were input and recoded with SPSS 25.0. Cases with obvious non-attentional response patterns or a large proportion of blanks were treated as invalid cases and were deleted. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were then conducted to validate the four surveys. EFA helps to identify whether the surveys have the internal structure (dimensionality) as the researcher hypothesized, providing validity evidence. The resulting factor structures of the surveys were then analyzed by CFA through Structural Equation Modelling (SEM).

As SEM is a powerful method dealing with multiple regressions simultaneously (Pedhazur, 1997), it can be used to test hypotheses regarding the associations among constructs (Schreiber, Nora, Stage, Barlow, & King, 2006). SEM was adopted in this study for two objectives. First, the measurement model for CFA purposes helped to validate the surveys. Second, the structural model can help to test if the proposed associations among the constructs fit the actual data. To evaluate the model fit for the SEM analysis for both purposes, a series of absolute indices as well as incremental fit indices were examined as goodness-of-fit indices.

To evaluate the model fit of both measurement models (for CFA) and the structural model in SEM, the criteria for the fit indices were selected as follows. CMIN/df should be lower than 5 (Wheaton, 1987); goodness-of-fit index (GFI) should be higher than 0.9 (Jöreskog & Sörbom, 1996); root mean square error of approximation (RMSEA) should be lower than 0.08; normed fit index (NFI) should be higher than 0.9 (Bentler & Bonnett, 1980); comparative fit index (CFI) should be higher than 0.95 (Hu & Bentler, 1999); incremental fit index (IFI) should be no lower than 0.95; and Tucker–Lewis index (TLI) should be no lower than 0.95 (Schreiber et al., 2006). In addition, root mean square residual (RMR) is also reported for comparison.

According to Hair (2006), the comparison EFA and CFA on separate samples can better ensure statistical robustness. The sample of 844 participants was thus randomly split into two subsamples, sample I and sample II, for EFA and CFA purposes respectively for all four surveys. EFA with oblimin rotation using SPSS was applied on sample I (n=422) for exploration of dimensionality. As recommended by Allison (2003) and Hair (2006), missing data were treated with the Maximum Likelihood Estimator. Because the AMOS software requires no missing data, the analysis using AMOS all used the data. Then CFA conducted on sample II (n=422) with AMOS further confirmed the internal structure. In this process, the other statistics including Cronbach's alphas were also calculated. The combination of EFA, CFA and other statistics were used to determine whether there were any items that needed to be deleted.

The surveys were finalized after evaluation of the EFA and CFA results, item deletion and measurement model modification. To test the hypothesized models, the structural model was then applied to the data (n=844). To compare the three proposed models (i.e., model A, B, and C in Figure 5, in which B and C is nested with model A), the χ^2 difference test was conducted for the nested models (i.e., model B and model C). In model B and C, the direct effect of STEM stereotypes on either self-efficacy or outcome expectations was constrained to zero. If there is no significance according to the χ^2 difference test between the models, which means the compared models are equally good to explain the data, the simpler model (model B or C) should be chosen for better parsimony. Some parsimonious fit indices, including the adjusted goodness of fit index (AGFI) and the Akaike information criterion (AIC), were also used to compare the models as suggested by Schermelleh-Engel, Moosbrugger, and Müller (2003) with higher AGFI and lower AIC indicating a better model fit.

5. Result

As this study was conducted in three conceptually linked parts using different methods addressing three research questions, the results are presented as three sections for better clarity.

5.1 Result for the qualitative survey and content analysis

The results for the qualitative survey, aiming to provide answers to the first research question about student's perceptions of STEM careers were generated by using content analysis on qualitative data gathered from students' drawing and writing. The results are summarized under two themes, namely (a) the characteristics in students' writing and drawing about scientists, engineers, and technologists at work and (b) the categories of careers summarized from students' presentations of scientists, engineers, and technologists.

5.1.1 Characterizing the work of STEM professionals'

In students' descriptions of the work of scientists (Figure 6), the most mentioned themes include researching (39.9%), experimenting (34.4%) and inventing (21.1%), followed by biology/medicine (21.1%) and chemistry (8.5%).

For the work of engineers (Figure 7), the most frequent themes in students' descriptions were buildings (50.9%), constructing buildings (33.0%), and designing (including redesigning/ refining design/ examining design/ testing design) (25.4%)

followed by fixing (9.6%), supervising others/ giving orders (9.2%) and other specific actions (7.1%), such as moving or mixing things.

In the students' descriptions of the work of technologists (Figure 8), the most-frequently mentioned themes included electric/ electronic devices (28.0%), coding (16.3%), fixing (16.1%), researching (12.2%), and other specific actions (10.6%), such as moving or mixing things.

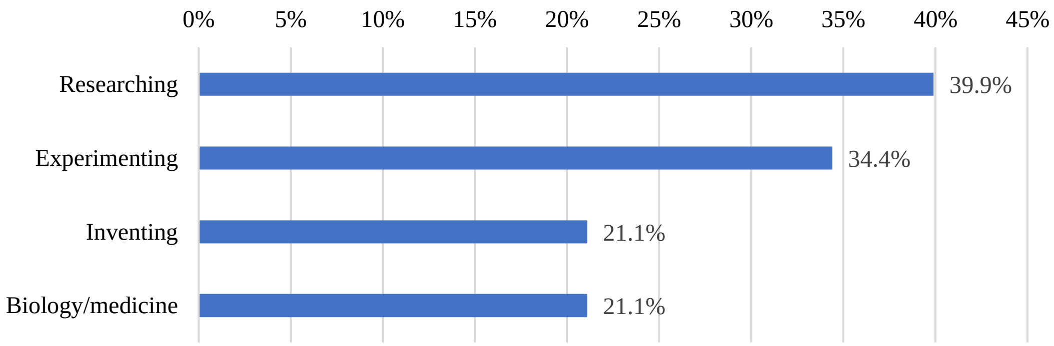


Figure 6. Themes with higher occurrences (>10.0%) in students' written descriptions regarding scientists' work

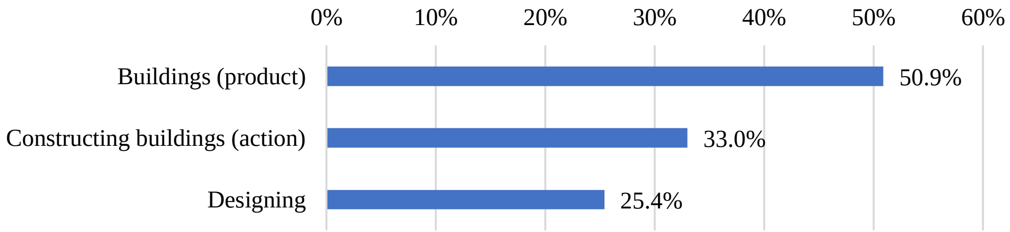


Figure 7. Themes with higher occurrences (>10.0%) in students' written descriptions regarding engineers' work

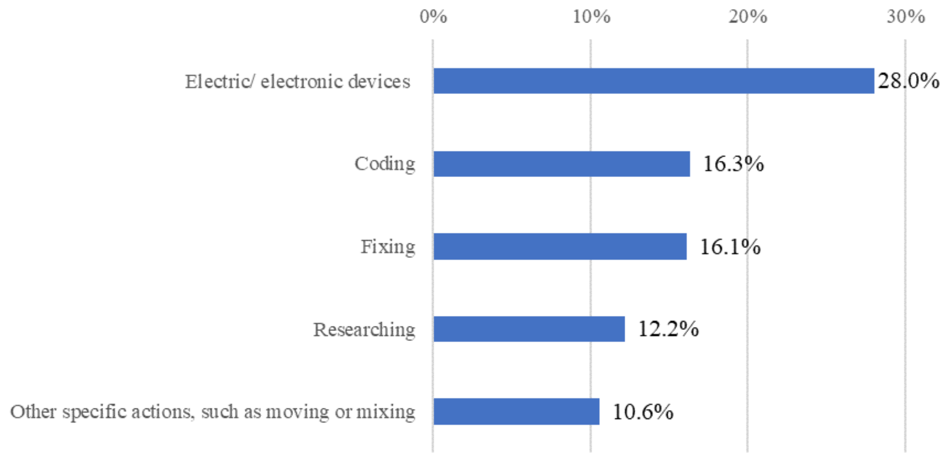


Figure 8. Themes with higher occurrences (>10.0%) in students' written descriptions regarding technologist' work

5.1.2 Characterizing the drawings of STEM professionals at work

The features with occurrences in students' visual presentations greater than 10% are presented in Figures 9, 10 and 11. The results indicate that the students tended to draw scientists working with test tubes/ flasks (76.7%) and at a lab desk (61.0%). The scientists they drew were often with smiling faces (40.8%), glasses/ goggles (27.3%), or with an explosive hairstyle (11.3%). Among these features, tubes/ flasks (76.7%) and a lab desk (61.0%) shows that students tended to associate scientists with laboratory work.

As for engineers, students tended to draw them working with safety helmets (43.5%), buildings/ scaffolds (35.3%), design drawings (23.6%), tools such as spanners/ hammers (23.2%), cranes/ derricks/ tractors/ excavators (19.2%), building materials (14.0%), notebooks (not computers) / papers (12.2%) or pens (10.8%) (Figure 10).

Students drew engineers working with others (10.8%), despite the requirement to "draw an engineer at work," compared to 0.9% of students' drawings of scientists and 3.0% of technologists depicting them working with others.

Technologists were often drawn as working with a computer (52.2%) and/or working with tools like spanners/ hammers (11.4%) (Figure 11). The occurrences of smiling faces were similar among the students' drawings of scientists (40.8%), engineers (40.6%), and technologists (40.4%).

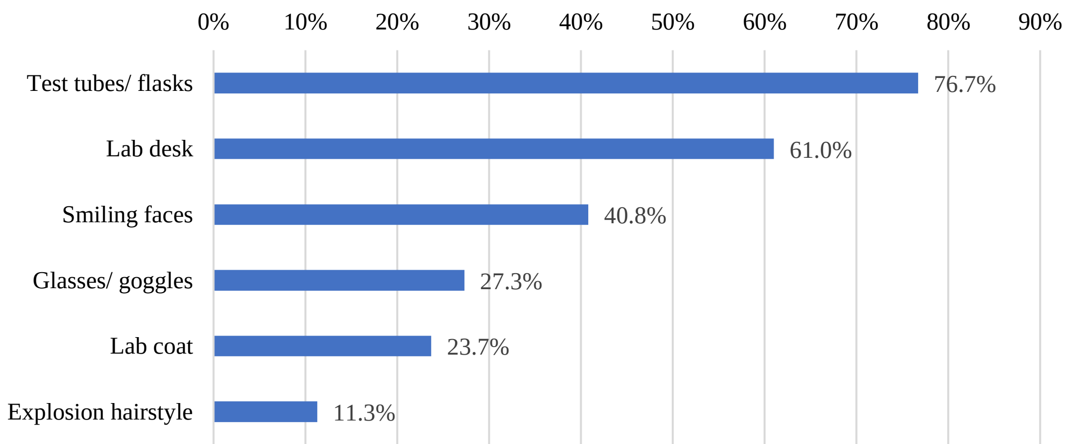


Figure 9. Features with higher (>10.0%) occurrences in the drawings of scientists

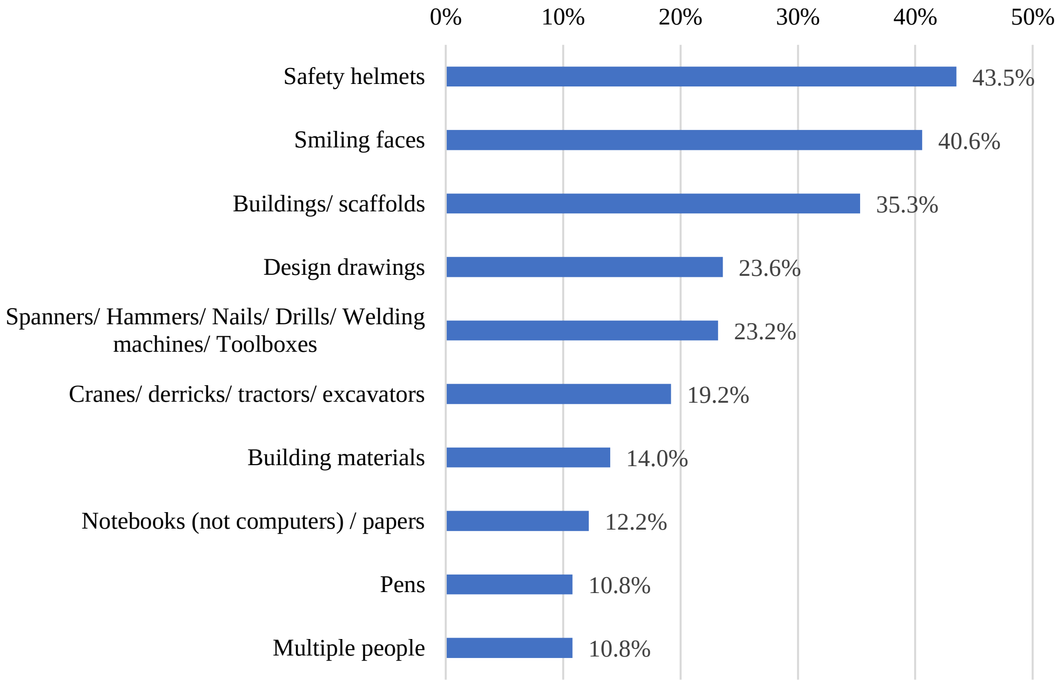


Figure 10. Features with higher (>10.0%) occurrences in the drawings of engineers

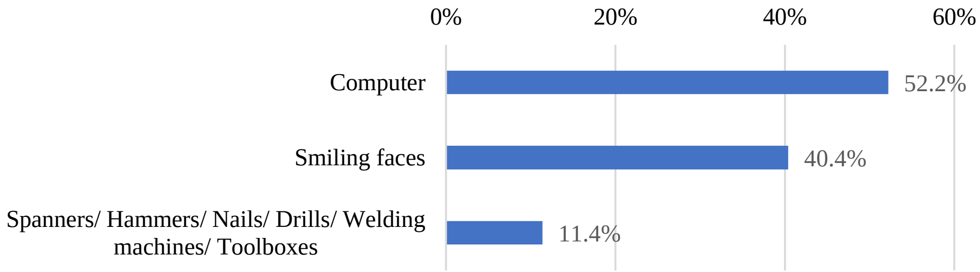


Figure 11. Features with higher (>10.0%) occurrences in the drawings of technologists

5.1.3 Categories of career perceptions in students' presentations of STEM professionals

After reviewing all the drawings of scientists, engineers, and technologists, the drawings were characterized into the following 10 career perceptions: researchers, inventors, construction workers, building designers, construction site coordinators, mechanic/ electric/ electronic technologists, programmers, clerks, engineers that solve problems, and aerospace engineers, (Table 8). Among the 10 categories, the first seven career categories were most common in students' presentations.

Table 8. Definitions and occurrences of the categories of students' presentations of STEM professionals (only occurrences >1% are shown)

Type of careers		Content of the work	Occurrences in according professionals		
			Scientists	Engineers	Technologists
1.	Researchers	Doing experiments/ conducting research	73.1%		13.5%
2.	Inventors	Inventing things	23.8%		8.4%
3.	Construction workers	Doing labor work to build a building		43.3%	
4.	Building designers	Designing buildings		26.0%	
5.	Construction site coordinators	Coordinating/ supervising others to build		10.0%	
6.	Mechanic/ electric/ electronic technologists	Doing skilful mechanic/ electric/ electronic works such as repairing and installing		10.0%	38.5%
7.	Programmers	Coding/ designing websites or apps			23.5%
8.	Clerks	Conducting general office tasks			5.3%
9.	Other engineers that solve problems	Working to solve certain problems		3.6%	
10.	Aerospace engineers	Working to launch spacecrafts			
	Invalid drawings/responses		1.6%	4.5%	8.6%

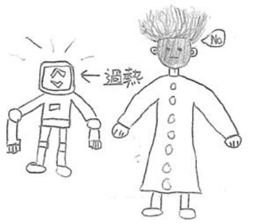
There were two major categories of careers in students' presentations of scientists, as shown in Figure 12. Most students drew a researcher (73.1%) and some drew an inventor (23.8%). The other categories all constitute less than 1% of all drawings of scientists.

Students also tended to draw and write about four categories of engineers, with many drawing construction workers (the 3rd category in Figure 12, constituting 43.3% of drawn engineers) or building designers (the 4th category in Figure 12, constituting 26.0% of drawn engineers) and a smaller number of students drew and wrote about construction site coordinators that supervise workers or monitor projects (the 5th category in Figure 12, constituting 10.0% of the drawn engineers) or mechanic/ electric/ electronic technologists (the 6th category in Figure 12, covering 10.0 % of the drawn engineers). A few students drew engineers who solve problems (3.6%). All the other categories of careers accounted for less than 1%.

Students' description:
1. doing research.
2. doing research and benefit humans

(1) Researchers

(73.1% of the scientists and 13.5% of the technologist)



Students' description[2]: doing technological experiment. 2. Produce machines for humans and bring convenience to humans

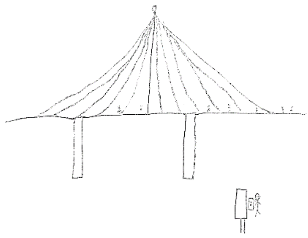
(2) Inventors

(23.8% of the scientists and 8.4% of the technologists)

Students' description:
1. building a skyscraper. 2. be safe.

(3) Construction workers

(43.3% of the engineers)



Students' description: draw a design graph. 2. design the bridge.

(4) Building designers

(26.0% of the engineers)

Students' description[3]:
1. supervising others to build houses
2. supervising

(5) Construction site coordinators

(10.0 % of the engineers)

Students' description[4]:
1. fixing electric devices

(6) Mechanic/electric/electronic technologists

(10.0 % of the engineers and 38.5% of the technologist)

Students' description:
1. programming 2.change the society and change the future

(7) Programmers

(23.5% of the technologist)

Figure 12. Typical categories of STEM professionals (only categories with percentages over 10% are shown; The first description after bullet the points is students' response to the question about what the drawn professional is doing and the second is students' description of what the most important task in the STEM professional's work is.)

[2] Translation of the words in the drawing: Overheat

[3] Translation of the words in the drawing: There! higher!

[4] Translation of the words in the drawing: broken

The technologists that students depicted in their drawings and writing mainly comprised three categories of careers. The most common category was mechanic/ electric/ electronic technologists (the 6th category in Figure 12, constituting 38.5% of the drawn technologists). This type of career was often drawn with computers or other technical products and was also presented in the drawn engineers. The second category of career was programmers who often work with computers and code, develop websites/apps or hack (23.5%). Moreover, 13.5% students drew technologists as researchers, followed by inventors (8.4%) and clerks (5.3%). The remaining categories of careers covered less than 1% of the drawn technologists.

5.2 Result for the interview and thematic analysis

The students' interview responses were analyzed using Thematic analysis. The results are summarized under two themes, namely (a) students' perceptions of STEM careers and (b) how perceptions of STEM careers influence students' career interest; these answer research questions 1 and 2 respectively.

5.2.1 Students' perceptions of STEM careers

Among the 31 students interviewed (including the pilot interview), a pattern could be found among students' responses regarding who scientists, engineers and technologists are. As shown in Table 9, most of the students indicated that researchers (84%) and inventors are scientists (84%) and that construction workers and building designers are engineers (84% and 87% respectively). Some students also assumed that construction site coordinators and technicians are also engineers (61% and 55% respectively). Students tended to think that programmers (97%), researchers (81%), inventors (74%) and technicians (61%) are STEM careers.

Table 9. Students' responses (n=31) regarding the listed careers being scientists, engineers, technologists, and STEM careers

	Scientist	Engineers	Technologist	STEM careers
1. Researchers	84%	3%	58%	81%
2. Inventors	84%	10%	35%	74%
3. Construction workers	3%	84%	6%	29%
4. Building designers	16%	87%	16%	58%
5．Construction site coordinators	0%	61%	13%	16%
6． Technicians (doing installation, repairing etc.)	10%	55%	35%	61%
7． Programmers	26%	6%	87%	97%

Scientists do research and experiments or/and invent

Many students believed that scientists' do research or experiment (e.g., "because scientists are responsible for studying these things, and then resolving mysteries." [Francis, 6th grade boy]). Many students also believed that scientists invent things (e.g., ''Because scientist all need to do research and then invent'' [Nancy, sixth grade girl]). Or they might categorize scientists as people who conduct scientific practices, mostly experimenting. For example, Elizabeth, a sixth-grade girl, explains:

"*(I) think researchers and inventors, and computer programmers are all scientists. (Interviewer: um-hum.) Because researchers and inventors all need to do experiments… (Interviewer: I see.) before they could make something new.*

(Interviewer: OK.) And computer programmers also …need to test apps to know if it is working."

Engineers do work related to buildings or/and design (buildings)

For engineers, most students believed that engineers do jobs related to buildings, architecture or civil constructions. This "engineers do things related to buildings" perception is referred to as "buildings" perception. And this perception is the main reason students interviewed chose "construction workers," "building designers," "construction site coordinators," and "technicians" as engineers; as one student explained, "these (careers) are all about buildings" (Nancy, 6th grade girl). Another important finding was that many students believed that engineers (at least a kind of engineers) do design work. This "engineers as designers" perception, or "design" perception was adopted by some students. Most students holding the "buildings" perception also acknowledged that engineers need to design, because adopting the "buildings" perception naturally leads to the perception that some engineers are responsible for designing buildings. However, some students may have confined the idea of "design" to only buildings while others did not.

For example, Ann, a fifth-grade girl who held both the "buildings" perception and the "design" perception responded that engineers are people who design buildings.

However, in the questionnaire, she chose building designer and computer programmer as engineers, showing that she believed that engineers do not only design buildings.

Interviewer: *Oh, I see… So, you choose 4 [building designer] and 7 [computer programmer]. Why you think 4 and 7 are engineers?*

Ann: *Engineers are people who, this designer needs to, needs to design things. And this should belong to engineers who are responsible for designing things.*

Interviewer: *Yes. And this one uses computers to design game apps, so this is also engineer.*

Interviewer: *OK, so engineers, could you please summarize who engineers are?*

Ann*: Design things.*

Technologists do work related to science or technological product

As for technologists, students' perceptions of them were more divergent than those of scientists and engineers. One popular perception was that technologists do jobs related to science or technological tools, especially computers. For example, a sixth-grade boy, Neil stated that inventors, technicians and computer programmers are technologists and explained that they are careers related to the functioning of technological tools:

"*Because technologists are people who invent things like I have mentioned computers, iPads, things like that, which is different from number 6, installing and fixing.*

Actually, after technologists complete these [inventions], if there is some problem, you need to build it up or fix it as it was. Then for computer programmers, he is a technologist, you need to code the programs, need to do programming."

In addition, there were many other kinds of perceptions, such as relating technologists to certain scientific or engineering practices (e.g., code, do research/experiment, invent, calculate etc.). However, a few students had no perceptions of who technologists are.

STEM careers are about STEM

The strongest responses about which professions best characterize a "STEM" career were computer programmers, researchers, and inventors. In interviews, several students believed that STEM careers were occupations that use STEM domains. "These [careers] are the ones that use STEM elements to complete their task" [Sandy, sixth-grade girl]. Some students believed that STEM careers are about technology, computers, or computer programs. Students' perceptions of STEM careers were aligned with their perceptions about STEM. For example, Robert, a sixth-grade boy, stated that technicians and computer programmers are STEM careers because "STEM stuff is stuff about computer programs." And another student, Francis (6th grade boy) claimed that STEM careers are about buildings, science and math. He said scientists, inventors, construction workers, building designers, technicians and computer programmers are STEM careers and explained that:

"*Because I remember STEM includes four fields. (interviewer: um-hum). One is about buildings, one is, I cannot remember the other three, but I can recall they are about science stuff anyway (interviewer: um-hum) , meaning is about general studies, math etc., because engineers need a few math stuff, because every building, every floor is probably three-meters, they need to know about calculations before they can be engineers. So, I think these are about STEM.*"

5.2.2 How perceptions of STEM careers influence students' career interest

Perceptions of STEM careers appeared to shape career-related outcome expectations and navigate self-efficacy to students' career interest. Through these perceptions of STEM careers (including the task, requirement and other attributes), they establish foundations for students to construct their STEM career interest.

Perceptions of STEM career as foundations of career interest/goals

Students' lack of perception of one career may lead to no aspiration or rejection. For example, some students lacked perception about technologists and claimed that they had never thought about being a technologist in the future. As shown in the interview with Keven (5th grade boy):

Interviewer: *Then have you ever thought about becoming a technologist?*

Keven: *Never thought about it because I don't know what it means.*

In another interview, Rachel, a 6th-grade girl, who was not sure about who engineers could not give conclusive answer about career interest in engineers before clarification about this concept：

Interviewer: *Have you ever thought about becoming an engineer in the future?*

Rachel: *Engineer…(long pause) are who?*

As stated above, students may hold narrow or biased perceptions of STEM careers and these perceptions were prerequisites of their construction of career interest or goals.

Perception of STEM careers as a direct shaper of outcome expectations which influence students' career interest

A significant theme, or pattern, regarding how students develop their career interest is the attribution of their career aspirations to being aware of the goal or task of STEM careers (e.g., scientists, engineers, technologists, doctors, inventors, etc.) which further lead to positive or negative outcome expectations that influence their career interest. This major theme was developed based upon some subthemes that emerged after convergence of the codes (the detailed coding process was shown in 4.2.5 in chapter 4). Three key subthemes under this theme were listed in appendix 9.

The quantification of some key themes and subthemes were also shown in appendix 9. The number of cases in which the themes/subthemes were present and the total occurrences of the themes/subthemes across the cases were calculated for promoting the objectivity of the thematic analysis.

Task/goals of STEM careers lead to expected altruistic values which is a major contributor to STEM career goals

Many students attributed their STEM career interest/goals to the belief that they can help other people or benefit society by doing the STEM work. This is a generally observed pattern for a wide range of STEM careers, showing students' altruistic orientation in their aspired careers. The expectation to help others was not always explicitly stated, but evidently many students presume that it is ideal if their future job could help others, and they took this aspect into consideration when constructing their career interest. For example, Eric, a fifth-grade boy explained his aspiration of becoming an interior designer as follows:

Interviewer: *Why you think you would like to be these kinds of designers?*

Eric: *Because if (you are) an interior designer you could make a building, a house or something for people to live. Then you could help others like this. For example, if people are homeless and you build a room for them, then they do not need to live on streets.*

In this case, Eric aspired to interior designers because of expected outcomes (help others), which was derived from the perceived goal (build houses/rooms) of interior designers' work.

In another example, Eric, a fifth-grade boy explained why he wanted to be a game designer as follows:

> "*Because I think games on phones have been very popular. Now in Hong Kong there are a lot of people playing cell phone games. Then if the future world is going to be somewhat digitalized and high-tech. So, becoming a game designer could benefit everyone.*"

In other words, the perceived altruistic aspects of STEM careers were associated with positive career-related outcome expectations, which focus on the social outcomes, and these positive outcome expectations help students construct STEM career goals.

Experiments/research lead to expected dangers/discomfort in scientists' work which deters students from aspiring to scientists

Regarding how students constructed career rejection, many students expressed concerns about the dangers of scientists' work, which they claimed was mainly associated with experiments, that could result in explorations or fires. A typical response given by Eric, a fifth-grade boy, shows how his perceived danger of scientists' work made him reject science as his career aspiration.

Interviewer*: …well, Lets' think about the career of scientists. Have you thought about becoming a scientist?*

Eric*:… emm. Never thought about it.*

Interviewer*: Oh, you never thought about it.*

Eric: *Because I think it is somewhat dangerous, such as the things in the test tubes, and other chemicals. If you were careless and made a mistake you could cause an exploration or fire or something like that.*

Students seemed to associate scientists' work with experiments and negative outcome expectations with experiments, including explosions, fire, and disease. For example, Philip, a fifth-grade boy, integrated some fantasy into his perception of scientists' work. He rejected scientific work as a career choice and explained that "*scientists need to do research, and probably use some animals to do some tests. If those animals become violent, you don't know what to do."* When asked about the disadvantages of becoming a scientist, Philip responded: "*You probably will produce a strong virus, and you may get infected. Then there will be other diseases*."

In another case, Michelle, a girl from sixth grade, indicated that scientists' workload in research work is large and the expected outcome of the research work as tiring deterred her from aspiring to scientists.

Interviewer: *…Well, have you ever thought about to be a scientist in the future?*

Michelle: *Yes, I did, before.*

Interviewer: *OK, have thought about it but you no longer want to do it?*

Michelle: *No.*

Interviewer: *No, why..?*

Michelle: *Because I watched many YouTube videos about scientists having so many things to do and so much to inquire. I think it's probably very exhausting and feel very tiring.*

<u>Construction work lead to expected discomfort/danger which deters students from aspiring to engineers</u>

One major pattern illustrating students' rejection of choosing engineering as a career was that students believe that engineers' work is to build buildings (perceptions of the task of STEM careers), which is unpleasant or dangerous (outcome expectation). For example, this very typical comment from a fifth-grade girl, Jane, shows how her perceptions of engineers as builders influenced her career interest.

Interviewer: *Well then, have you thought about becoming an engineer?*

Jane: *Could be very tiring or get sunburnt.*

Interviewer*: Why would you think it could be tiring or you could get sunburnt?*

Jane*: Because usually, things like to build some buildings would make (people) feel very heavy or something like that.*

In another case, Keven, a 5th grade boy, also rejected becoming an engineer in the future because he had negative outcome expectations of being in danger and unpleasant.

Interviewer*: ... Well, then let's think about engineers, ever thought about becoming an engineer in the future?*

Keven*: No.*

Interviewer*: Why do you think not?*

Keven*: Because being an engineer feels so hot and puts your life in danger.*

Interviewer*: In danger? How?*

Keven*: Because if you become an engineer, you may fall, fall off when you are up there working. And then you will be dead, very dangerous.*

Interviewer*: So, you mean engineers need to be somewhere very high.*

Keven*: Yes. And probably will be very uncomfortable working under sunlight. Need to work at night too, working day and night.*

Keven's negative outcome expectations seemed to be associated with his stereotypical perception of engineers' work that engineers may do some handy work on the construction site. In the interview, Keven express his stereotypical view of engineers being associated with buildings and construction. In the questionnaire, Keven linked construction workers, building designers, construction site coordinators and technicians with engineers. And his justification is as follows:

Keven*: …because construction workers are about fixing or building something (Interviewer: Um-hum), so they are about engineering (Interviewer: Ok). Then building designer, because here we say buildings are to build something, related to build things, so they are included too. Then construction site coordinators are people watching those construction workers, and building designers work. (Interviewer: OK). So, they are included. Then… (Interviewer: Technician?) Technicians do installing and fixing, both are related to buildings, they are also engineers, then…*

Interviewer*: So, you think engineers they all are…*

Keven*: They build something.*

Likewise, another 6th grade boy named Frank also rejected engineering as his career aspiration because it is "tiring":

Interviewer*: Well for other occupations, have you thought about becoming an engineer?*

Frank*: Engineer… I don't have special feelings about becoming an engineer. Because my father works for interior designer. Then we, my father often tells me, try not to learn this as a job, like this. Because he said it is very tiring (Interviewer: I see.) Yes.*

Interviewer*: What do you think, do you think it is tiring?*

Frank*: Because I have seen it is very exhausting. Because sometimes my father doesn't have lunch. I think he was very tired. I brought him lunch… it's somehow tiring.*

According to Frank, his father's job "belongs to the technician category, meaning to help people decorating houses, help people installing furniture and stuff." And the job "needs more strength, because he is the technician type such as helping others to floor."

Perceptions of STEM careers can navigate students' self-efficacy to career interest

This assertion was supported by the major theme that describes how students' perceptions of STEM careers explicitly or implicitly navigate the process of attributing their career interest to their self-efficacy. In the interviews, it was evident that higher self-efficacy may lead to specific career aspirations and lower self-efficacy may contribute to rejecting certain careers. And this effect may be navigated by students' perception of a task or requirement of a given STEM career. For example, Lisa, a fifth-grade girl, showed little interest in being a scientist because she thought she was not good at memorizing and thinking fast.

Interviewer: *Well, have you thought about becoming a scientist?*

Lisa: *a little.*

Interviewer: *A little bit, but not really, now?*

Lisa: *no, it's very hard.*

Interviewer: *oh, it's hard. Why do you think it's very hard?*

Lisa: *because there's a lot to memorize.*

Interviewer: *oh, a lot to memorize. Oh, why? What do you need to memorize?*

Lisa: *math.*

Interviewer: *oh, math, math. Anything else? (Lisa: yes). Like what else?*

Lisa: ... *(pause)*

Interviewer: *no? (B: no.) Oh, never mind. Is there anything else you would find difficult other than memorizing?*

Lisa: ... *(Long pause) thinking fast.*

Interviewer: *Oh, he needs to think fast. Why do you think he needs to think fast?*

Lisa: *because science has a lot of... A lot of things.*

Interviewer: *Oh, a lot of things... to think?*

(Lisa nodding)

Lisa explicitly indicated that scientists need to memorize a lot of mathematics and scientists need to think fast. These perceptions about the requirement of scientists (memorizing and thinking fast) reveal Lisa's lower self-efficacy which had reduced her interest in becoming a scientist in the future.

The following example (Nancy, a girl from grade six) shows how one student's narrow perceptions about the task of engineers (design buildings only) and lower self-efficacy in designing buildings together caused her to have little interest in becoming an engineer.

Interviewer: *Then let's think about other jobs, such as engineers. Have you thought about becoming an engineer?*

Nancy: *A little.*

Interviewer: *A little. Well, when do you feel like doing this?*

Nancy: *Very complicated, even then I don't feel like doing those things.*

Interviewer: *Very complicated. What do you think is complicated?*

Nancy: *There will be, there will be big clients asking me to design those grand houses, very big one. Then it will be somehow difficult.*

Interviewer: *Oh, you think there will, so, you think engineers design buildings?*

Nancy: *Design some houses.*

5.3 Results for the quantitative survey and SEM

The SEM analysis includes the results of the validation of the four surveys (one translated survey and three newly developed surveys) and testing and comparing of the hypothesized models. After finalizing the model, the SEM result can help examine the associations among STEM stereotypes, STEM self-efficacy, outcome expectations and career interest.

5.3.1 Survey validation

Before the survey validation, a series of parameters were checked. The recoded items all fell within a reasonable range of 1 to 5. The skewness and kurtosis of all items (-3 to 3) indicate fair normality as suggested by Kline (2005). In addition, both Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) suggest that the data for the four surveys is suitable to perform EFA.

EFA and CFA analysis of the surveys

In the end, the four surveys all exhibited one-factor structure according to EFA and CFA. The Cronbach's alphas of the four surveys ranged from .814 to .901 indicating good reliability.

<u>Survey 1: STEM stereotypes</u>

Four items were deleted due to lower factor loadings or poor model fit after several rounds of EFA and CFA. The four items deleted included two newly added items and two items from the original MASS scale (“are not good athletes” and “spend all their time alone”). The factor loadings of the remaining items in EFA ranged from .685 to .879 (Table 10). The CFA result confirmed that after deleting four items, the survey data fit well under the one-dimension model, which is consistent with the original version (Garriott et al., 2016). The final standardized regression weights for the revised items in CFA ranged from .679 to .823 (Table 10). The fit indices of the CFA results (Table 11) indicated that the data fit the CFA model well. The final Cronbach’s alpha for the revised MASS was .884.

Table 10. EFA and CFA results for MASS survey

Item (all items begin with “People doing STEM-related jobs”)		Factor loadings in EFA (n=422)	Standardized regression weights in CFA (n=422)
MASS-1	are not attractive	.685	.685
MASS-2	are weird	.830	.790
MASS-3	have poor social skills	.879	.823
MASS-4	do not have many friends	.796	.806
MASS-5	have bad hygiene	.780	.756
MASS-8	have a hard time making friends	.765	.679

Table 11. Fit indices of the SEM measurement (CFA) models for the surveys (n=422)

	Absolute Fit Indices							Incremental Fit Indices			
	χ^2	d*f*	*p*	χ^2/d*f*	GFI	RMR	RMSEA	NFI	CFI	IFI	TLI
STEM stereotypes	30.232	9	*p*< .001	3.359	.977	.029	.075	.977	.983	.972	.983
STEMaSE	92.296	41	*p*< .001	2.251	.966	.029	.055	.961	.978	.978	.964
STEMOE	.237	1	*p*=.626	.237	1.000	.004	.000	1.000	1.000	1.001	1.007
STEMCI	15.210	5	*p*=.010	3.042	.986	.024	.070	.989	.992	.992	.985

Survey 2: STEM self-efficacy in STEM activities (STEMaSE)

Based on the results from screen plot and Eigenvalues, the STEMaSE survey exhibited a one-factor structure in the EFA result using sample I (n=422). The EFA factor loadings for the items ranged from 0.438 to 0.760 (Table 12). Errors were allowed to be correlated among some items (Figure 13) because there were some same/similar phrases among several items, such as “inquiry” and “research”, which could trigger students’ similar response patterns. The goodness-of-fit indices showed satisfactory results (Table 11). The CFA regression weights of the items ranged from 0.469 to 0.789 (Table 12). The CFA result confirmed the one-factor structure for the 12-item STEMaSE survey.

Table 12. EFA and CFA results for STEMaSE survey

	Item	Factor loadings in EFA (n=422)	Standardized regression weights in CFA (n=422)
STEMaSE-1	I am able to propose an inquiry (research) question	.629	0.668
STEMaSE-2	I am able to design steps of inquiry (research)	.655	0.654
STEMaSE-3	I am able to conduct scientific inquiry (research)	.670	0.669
STEMaSE-4	I am able to arrange and represent findings of inquiry (research)	.682	0.626
STEMaSE-5	I am able to use technological product	.438	0.469
STEMaSE-6	I am able to define the problem to be solved	.646	0.609
STEMaSE-7	I am able to design solutions to the problems	.760	0.699
STEMaSE-8	I am able to test and compare different solutions	.730	0.789
STEMaSE-9	I am able to refine solutions	.711	0.756
STEMaSE-10	I am able to collect data	.740	0.640
STEMaSE-11	I am able to analyze data	.739	0.587
STEMaSE-12	I am able to represent the data with graphs	.663	0.512

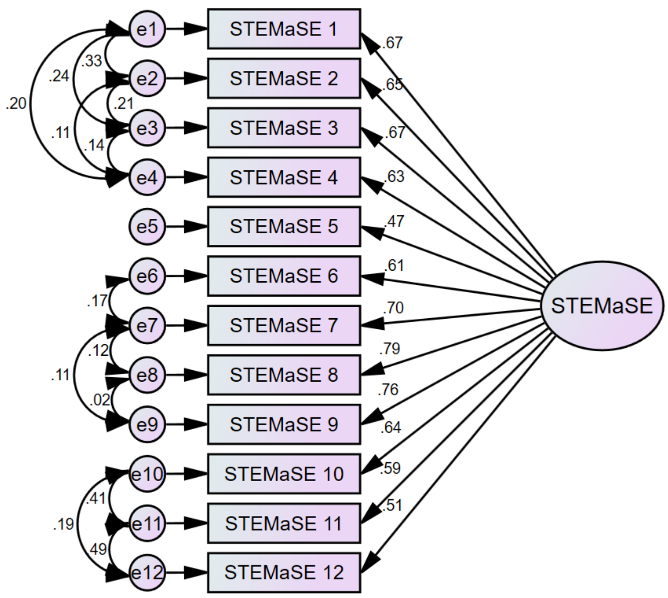


Figure 13. Confirmatory factor analysis model for STEMaSE survey (The standardized regression weight of each item is shown above the arrow directing from the latent variable “STEMaSE” shown in the oval pointing to the rectangles representing the items)

<u>Survey 3: STEM outcome expectations (STEMOE)</u>

According to the results from EFA and CFA, the 5th item in the STEMOE survey (“If I do STEM-related jobs, I can be respected by others”) was deleted since it had a low standardized regression weight (less than 0.4) in the CFA model. Moreover, correlated errors were allowed between items 3 and 4 in CFA because of shared or similar phrases and sentence structure (Figure 14). After deleting item 5 and model modification, the survey exhibited one-factor structure in both EFA and CFA.

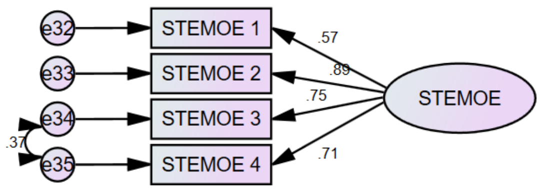


Figure 14. Confirmatory factor analysis model for STEMOE survey (The standardized regression weights of each item is shown near the arrow directed from the latent variable “STEMOE” shown in oval to the rectangles that represent the items)

The factor loadings in EFA for the four items ranged from .646 to .881 while the standardized regression weights in CFA ranged from .568 to .887 (Table 13). The fit indices of the CFA can be seen in Table 11. Although Model Chi squared showed significance, which is easily influenced by large sample sizes, other fit indices show that the survey data fit well under the one-factor CFA model. The final four-item STEMOE survey had a Cronbach's alpha of .814.

Table 13. EFA and CFA results for STEMOE survey

Item (Each item begins with "If I do STEM-related jobs,")		Factor loadings in EFA (n=422)	Standardized regression weights in CFA (n=422)
STEMOE-1	my parents will be satisfied	.646	.568
STEMOE-2	I can help others	.811	.887
STEMOE-3	I can make contributions to the society	.881	.748
STEMOE-4	I can make the world a better place	.813	.709

<u>Survey 4: STEM career interest (STEMCI)</u>

EFA suggested a one-factor solution for the four-item STEMCI survey and the CFA results confirmed the one-factor model. The CFA fit indices (Table 10) and other statistics suggest that no item needed to be deleted. The Cronbach's alpha for the five-item survey was .901. The EFA factor loadings for the items ranged between .788 to .899 and the CFA standardized regression weights ranged from .693 to .917 (Table 14).

Table 14. EFA and CFA results for STEMCI survey

	Item	Factor loadings in EFA (n=422)	Standardized regression weights in CFA (n=422)
STEMCI-1	I am very interested in STEM-related jobs	.846	.761
STEMCI-2	I hope my future job could by related to STEM	.899	.917
STEMCI-3	My dream career is related to STEM	.895	.853
STEMCI-4	I hope my future job can use STEM	.788	.807
STEMCI-5	I am interested in being a scientist, an engineer or a technologist	.798	.693

To conclude, all four surveys had a one-factor structure according to the results from EFA and CFA, consistent with the hypothesized dimensionality of the four surveys. The final Cronbach's alphas of the four surveys range from .814 to .901 (Table 15), indicated satisfactory to good reliability.

Table 15. Cronbach's alphas of the finalized surveys (n=844)

Survey	Measured variable	Item example	Item number	Cronbach's alpha
MASS	STEM stereotypes	People doing STEM-related jobs do not have many friends	6	.884
STEMaSE	Self-efficacy in STEM activities	I am able to design solutions to problems	12	.897
STEMOE	STEM Outcome expectations	If I do STEM-related jobs, I can make the world a better place	4	.814
STEMCI	STEM career interest	I hope my future job could be related to STEM	5	.901

5.3.2 Testing and comparing the hypothesized models

The path between STEM stereotypes and STEM career interest in model A (Figure 5 in chapter 3) was not significant (standardized coefficient =-.058, p=.096), suggesting this model may not be the ideal model. A χ^2 difference test was then applied to compare model A and its three nested models (model B, C, and D).

As shown by the χ^2 difference test, there were significant differences between model A and model B (χ^2= 23.697, d*f*=1, p< .001) and model A and model C (χ^2= 27.936, d*f*=1, p< .001). This result shows that model A explains the data significantly better than model B and C. As model G was nested within model B and model C, it could be assumed that model A also fit the data better than model G. However, there were no significant differences between model A and D according to the χ^2 difference test (χ^2= 2.760, d*f*=1, p=.097).

Based on the χ^2 difference test, the insignificant coefficient of the effect of STEM stereotypes on STEM career interest in model A and the AIC and AGFI indices (Table 16) altogether suggest that model A and D could be viewed as an equally good fit to the data. For parsimony, model D was chosen over model A, which in turn, was better than model B, C and G. In model D, the R square (or Squared Multiple Correlations in AMOS) for the STEMCI (STEM career interest) is .310, showing that this model could explain about 31% of the total variance of the outcome variable.

Table 16. Fit indices of the SEM structural models (n=844)

	Absolute Fit Indices							Incremental Fit Indices				Parsimony Fit Indices	
	χ^2	D*f*	*p*	χ^2/df	GFI	RMR	RMSEA	NFI	CFI	IFI	TLI	AGFI	AIC
Model A	810.888	304	p< .001	2.667	.932	.052	.044	.931	.956	.956	.949	.915	958.888
Model B	834.585	305	p< .001	2.736	.930	.061	.045	.929	.954	.954	.947	.913	980.585
Model C	838.824	305	p< .001	2.750	.929	.074	.046	.929	.953	.954	.946	.913	984.824
Model D	813.648	305	p< .001	2.668	.932	.054	.044	.931	.956	.956	.949	.915	959.648
Model E	838.299	306	p< .001	2.740	.929	.065	.045	.929	.954	.954	.947	.913	982.299
Model F	842.877	306	p< .001	2.754	.929	.079	.046	.929	.953	.953	.946	.913	986.877
Model G	865.287	306	p< .001	2.828	.927	.087	.047	.927	.951	.951	.944	.910	1009.287

Model E and model F should be compared with model D for better parsimony since they were nested within model D. The χ^2 difference test indicated a significant difference between model D and the two nested models, model E (χ^2= 24.652, d*f*=1, p< .001) and F (χ^2=29.229, d*f*=1, p< .001). In addition, model D had a higher AGFI (AGFI=.915) and lower AIC (AIC=959.648) than model E (AGFI=.913; AIC=982.299) and model F (AGFI=.913; AIC= 986.877), indicating that model D fit the data better than models E and F. In general, the goodness-of-fit indices also suggest that model D fit the data better than models E and F (Table 16).

Therefore, model D (full indirect effect model) was selected over other models as the best fit to the data. The model, with χ^2=813.648, p< .001; χ2/df =2.668; GFI=.932; RMR=.054; RMSEA=.044 (90% CI [.041, .048]); NFI=.931; CFI= .956; IFI=.956; TLI=.949 (Table 15), showed overall good fit. The SEM model of model D (the full indirect effect model) is shown in Figure 15.

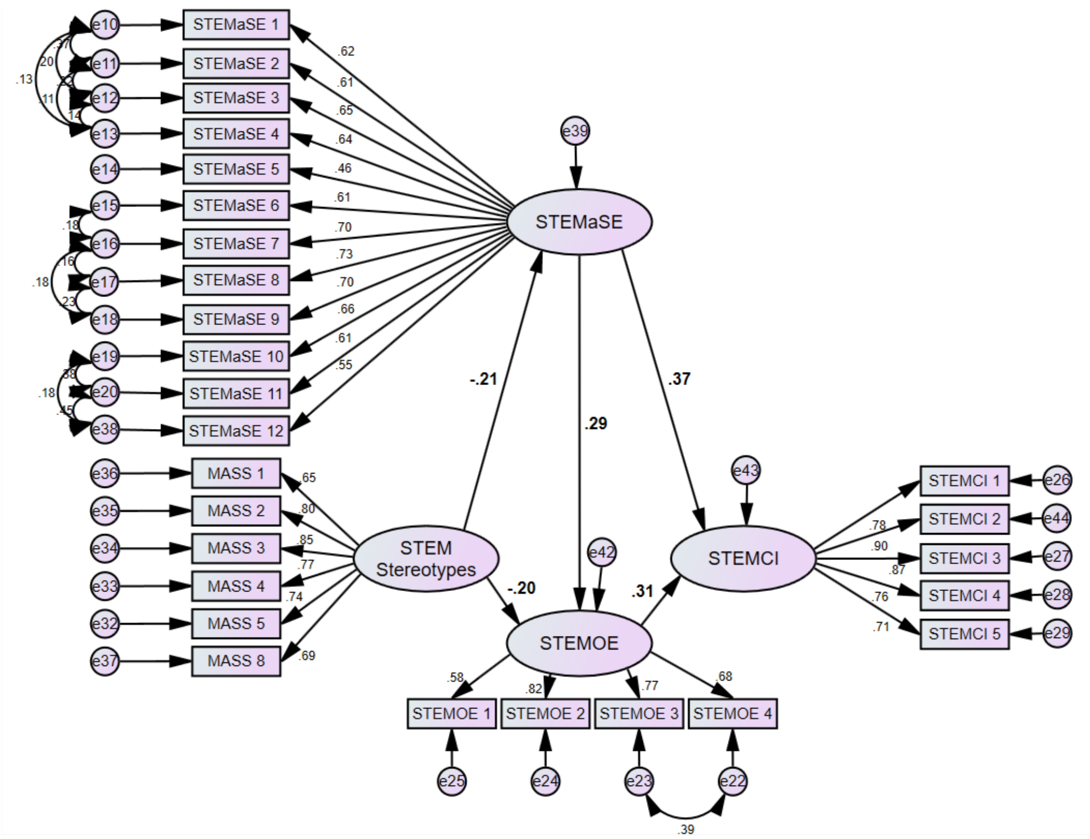


Figure 15. The final SEM model (Model D: the full indirect effect model). All path coefficients and factor loadings are standardized. All direct relationships between latent variables were significant ($p < .001$)

As shown in Table 17 and Figure 15, students' STEM stereotypes negatively and significantly predicted their STEM self-efficacy (standardized coefficient = -.21, $p < .001$) and STEM career-related outcome expectations (standardized coefficient= -.20, $p < .001$). And STEM self-efficacy positively predicted STEM career-related outcome expectations (standardized coefficient= .29, $p < .001$) and STEM career interest (standardized coefficient= .37, $p < .001$). STEM career-related outcome expectations also significantly predicted STEM career interest with a standardized coefficient of .31 ($p < .001$).

Table 17. Results of direct effects from SEM

			β	B	S.E.	C.R.[5]	*p*
STEMASE	←	STEM Stereotypes	-.211	-.163	.032	-5.174	***
STEMOE	←	STEMaSE	.288	.317	.050	6.353	***
STEMOE	←	STEM Stereotypes	-.198	-.168	.035	-4.769	***
STEMCI	←	STEMaSE	.374	.602	.067	8.917	***
STEMCI	←	STEMOE	.307	.449	.061	7.371	***

[5] The C.R. is calculated by dividing the regression weight estimate by the estimate of its standard error.

6. Discussion

The findings of each part (qualitative survey investigation, interviews, and SEM analysis) are first summarized in this chapter. The remaining part of this chapter discusses the findings, organized in a way that can address the three main research questions.

6.1 Summary of findings

The aim of the qualitative survey and content analysis was to examine students' perceptions of three STEM professionals. The results show that students tended to relate scientists with laboratory-related features, doing research or inventing; engineers were related to building construction; and technologists were related to technological products. In addition, seven major categories of careers formed students' perceptions of scientists, engineers, and technologists.

The aim of the interviews was to examine how students negotiate among their perceptions of self and careers and construct their career interest. The results show that students' perception of the tasks or requirements of a given STEM career may navigate their self-efficacy which may lead to either career aspiration or rejection. The perceived tasks or working conditions of STEM careers may lead to either positive or negative outcome expectations that may lead to career aspiration or rejection. Specifically, the perceived task of scientists (doing research or experiments) held by many students can often lead to negative outcome expectations (e.g., danger, exploration, or fire) and students may thus reject becoming a scientist in the future. The perceived task and working conditions of engineers, i.e., builders who work on the construction sites, by many students may also lead to negative outcome expectations (e.g., falling and discomfort, feeling tired and hot) which in turn can deter them from aspiring to become engineers. However, many students aspire to STEM careers because they expect altruistic outcomes due to the task and goal of the STEM professional's work.

The aim of the quantitative survey and SEM analysis was to examine the relationships among students' STEM stereotypes, self-efficacy in STEM activities, outcome expectations and students' STEM career interest. The results showed that students' STEM stereotypes negatively predicted their self-efficacy in STEM activities and STEM career-related outcome expectations. Furthermore, STEM stereotypes had an effect on STEM career interest via STEM self-efficacy and outcome expectations. The results also revealed that students with stronger STEM stereotypes tended to have lower self-efficacy in STEM activities and lower levels of STEM career-related outcome expectations, and these could lead to lower interest in entering STEM fields. These findings are crucial for explaining how students' stereotypes of STEM careers may further influence their future career options.

6.2 Connecting the findings

Findings from the qualitative survey gave a detailed depiction of the image of several STEM careers in students' minds and from interviews and quantitative survey with SEM analysis explored how students' perceptions of STEM careers may further impact their construction of career interest; the SEM analysis focused on the role of STEM stereotypes and the interviews focused on the role played by general perceptions of STEM careers. The three components are connected like pieces of a puzzle to provide a bigger picture to study how students develop STEM career aspirations and interests based on their perceptions of STEM careers.

Overall, the major findings from the qualitative survey aligned with those of the interviews. First, the categorizing result regarding what careers are included under the job titles, “scientist,” “engineer,” and “technologist” in the qualitative survey (Table 8 and Figure 12) was generally consistent with the interview results (Table 9). This consistency provides some support for part of the qualitative survey results because the findings were generated from different samples and methods. In the qualitative survey, the categorization was generated from the researcher’s content analysis of students’ drawings and written responses (n=564). In the interviews, the categories were given to students as options and students could to choose to be included under the concepts of scientists, engineers and technologists, although the sample for the interviews is rather small (n=31).

In both the results from qualitative survey and the interviews, students tended to associate scientists with lab work (researching and inventing), engineers with construction and architecture (e.g., designing and constructing buildings) and technologists with work related to technological products (coding, fixing etc.). Although, there were some alternative perceptions held by students as well, the overall tendency was quite clear according to these findings.

As STEM stereotypes are assumed to be part of perceptions of STEM careers, a certain level of connection was expected between the results of the interviews and the

SEM analysis. The different methodologies between the interviews and the SEM analysis was expected to lead to a different result. Therefore, merely connection, rather than consistency, was operative to seek between the findings from interviews and the SEM analysis. However, the connections are not evident.

One of the reasons may be that, in the interviews, STEM stereotypes (geeky, unsocial, not sporty) were not very commonly mentioned by the students. This is probably because that the STEM stereotypes were more implicit in students' perceptions than some other features of STEM professionals, such as the requirements or tasks of their work. Students may not have been willing to share negative STEM stereotypes because they may be aware that holding such negative stereotypes is offensive. In addition, STEM stereotypes should be viewed as different constructs than other perceptions of STEM careers, such as requirements, content or other features of STEM professionals' work. Thus, STEM stereotypes may impact other constructs, such as self-efficacy, outcome expectations and career interest, differently than other perceptions of STEM careers (such as perceptions of the content of STEM professional's work).Therefore, the association between the findings from the qualitative survey and the interviews could be viewed as supplemental rather than validating each other.

6.3 Misplaced perceptions of STEM careers

The findings of the qualitative survey and the interviews is consistent with previous studies regarding perceptions of scientists but inconsistent with other studies regarding perceptions of engineers. The findings of perceptions of technologists and STEM careers fill the research gaps in previous studies.

6.3.1 Perceptions of scientists, engineers, technologists and STEM careers

On the one hand, similar to the studies by Chambers (1983), Emvalotis and Koutsianou (2018), and Losh, Wilke and Pop, (2008), most elementary students in this study drew scientists as researchers doing lab work with experimental instruments, and some drew less-common images of scientists as inventors (see Buldu, 2006). On the other hand, in some previous studies, students tended to perceive engineers' work as repairing and building things (Capobianco, Diefes-Dux, Mena, and Weller 2011; Fralick, Kearn, Thompson, and Lyons, 2009; Karatas, Micklos, and Bodner 2011; Lachapelle, Phadnis, Hertel, and Cunningham 2012). However, in the present study, the drawings of engineers' work mostly related to constructing buildings or architecture. In addition, many of the drawings of engineers at work featured construction, such as construction sites or tools, which was covered by a much smaller percentage of occurrence in previous studies (Capobianco et al. 2011; Lachapelle, Phadnis, Hertel, and Cunningham 2012).

According to the survey results from the students who were interviewed (Table 9), although also diversified, students' understanding of the concept of "STEM careers" was generally appropriate, including researchers, inventors, programmers and technicians. This result shows that upper-elementary students generally interpreted the concept of "STEM career" to include various careers in STEM domains, and much more inclusive than scientists, engineers or technologists. The inclusiveness of the concept of STEM careers provides evidence supporting the use of “STEM career” in the surveys used in the SEM analysis in this study.

6.3.2 Engineering careers were not taken as engineers

Inconsistent with previous findings stating that students lack perceptions of engineers (Fralick, Kearn, Thompson, and Lyons 2009), the results in the present study show that many students do hold perceptions of some engineering careers, but they put their perceptions of these engineering careers into their perceptions of scientists or technologists and seldom perceive them as engineers. Among the seven major categories of careers in the students’ drawings, inventors, building designers and programmers were three types of engineering careers, or engineers. These three categories of engineering careers constituted 30% of all presentations by students, compared to 29% of presentations about careers doing research work. However, the students tended to assign these engineering careers to either scientists or technologists according to both the qualitative survey and the interviews. For example, inventors were presented in students’ perceptions of scientists, and programmers were presented in their perceptions of technologists, indicating detachment of these engineering careers and the concept of engineers. In other words, student may have perceptions of these engineering careers, but they do not believe they are engineers. Among these engineering careers, only building designers, were assigned to students’ perceptions of engineers.

The results of the qualitative survey and the interviews also showed that many students mentioned the concept of inventing in scientists' work, while inventing was seldom mentioned in their perceptions of engineers' work. It is true that inventors could be viewed as scientists as many scientists invent, but invention by nature is more related to engineers' than to scientists' work. This is most likely due to inventors often being introduced as scientists, such as Thomas Edison, in science classrooms, textbooks and in social media.

In addition, although a programmer is an engineering career and programming is an engineering practice, most students drew programmers as technologists rather than engineers This is perhaps because students tend to assume that technologists are people handling technological tools like computers. They may also believe that clerks, which constituted a very small proportion of presentations of technologists, and who do general office work and often work with a computer, are technologists.

6.3.3 Plausible reasons behind the misplaced perceptions of careers

Students' presentations of engineers at work were biased, presented as neither inventing nor coding. In the most common categories of engineers in students' presentations, only building designers are engineering careers, while other categories of careers (construction workers, construction site coordinators and mechanic/ electric/ electronic technologists) are technologists. Generally, students tended to include different careers related to the process of building and architecture in their perceptions of engineers, doing work such as "moving things," "build architecture" or "supervise others to build." It is possible that students may tend to integrate the careers they see in their everyday lives that are related to buildings into their perceptions of engineers and thus gradually accumulate biased or stereotypical perceptions about engineers.

The reason why some of the students who participated in the qualitative survey and interviews believed that engineers' work is related to civic construction may originate from the Chinese language. The word "engineering" in Chinese has another meaning translated as "project," in English which usually refers to civil projects. Students may therefore naturally assume that engineers have close associations with civil projects or constructing buildings. Thus, students' perceptions and attitudes towards STEM careers, such as career interest, could be "misplaced." The biased perceptions of engineers' work suggest a need for intervention to introduce a more realistic view of STEM careers, especially engineering careers to students.

In Hong Kong, elementary science is integrated into a core subject in the elementary curriculum called General Studies. In the General Studies curriculum, 1st to 3rd grade students are expected to learn about scientists and inventors as well as their contributions. This may explain why researchers and inventors were the major categories of careers that students presented. Moreover, according to the curriculum, Hong Kong's 4th to 6th graders are expected to know about the development of science and technology and its impact on society, which may promote their understanding of technologists' work. However, there is an obvious lack of instruction regarding engineers, their work and impact on society in the curriculum. This may be one of the reasons why most students did not include many engineering careers (including programmers and inventors) in their perceptions of engineers.

6.4 Perceptions of STEM careers and the impact on career interest

The results of the SEM analysis show that STEM stereotypes could have an influence on elementary students' STEM career interest via STEM self-efficacy and outcome expectations. This finding explains the often-neglected role of students' STEM stereotypes in students' career development and suggests that educators should pay attention to students' STEM stereotypes and make efforts to transform stereotypical perceptions of STEM careers into more comprehensive, realistic, and diversified perceptions. In this regard, he developed surveys in the SEM analysis (STEMaSE, STEM outcome expectations and STEM career interest) could be used as valuable assessment instruments in STEM education as they exhibited good reliability and validity.

The interviews, on the other hand, revealed how general perceptions of STEM careers are not limited to stereotypes and have a role to play in students' construction of their career aspirations or rejections of careers. The interview responses generally aligned with the perceived typology of scientists, engineers, and technologists found in the qualitative survey. The results suggest that students' orientation of certain careers was based on their perceptions of these careers. Students' perceptions of STEM careers, especially the perceived task or goal of the career, could lead to positive and altruistic outcome expectations which may lead to career aspirations. The perceived task/condition that may lead to danger or discomfort may create negative outcome expectations and thus make students reject these STEM career options. Sometimes these perceived danger/ discomforts originated from a biased understanding of STEM careers. In addition, students' self-efficacy which may lead to their career aspiration and rejection, was also based on their perceived requirements of STEM careers.

6.4.1 The role of perception of STEM careers in constructing career interest/goals

The interviews provided a more detailed and complex picture about students' construction of their career aspirations and rejections. The process may involve a comparison between students' perceptions of careers, and their perceived self (including their abilities, interests and expectations for the future), all of which may not have been explicitly mentioned in the interviews.

Perceptions of STEM careers in the construction of "sense of fit"

When students attribute their career aspirations or rejection to their high/low self-efficacy, they may have been comparing their perceived self-efficacy to the requirement/task of the career and to form a sense of level of "fit." For example, students may have assumed that scientists are good at memorizing scientific concepts. In this case, the students may have been subconsciously evaluating their ability in memorizing and their high ability (self-efficacy) may have led to a sense of fit between their self-concept and becoming a scientist. Likewise, when students attribute their career aspirations or rejection to their positive or negative outcome expectations, they may have compared the expected outcome of possible career choices with the expected outcome for their own future. For example, students may expect an engineer to travel a lot and this may be a negative outcome expectation for them because they may hope to spend more time with their family in the future. This comparison and seeking for a fit between outcome expectations and students' expectations echoes the findings of Mark's study (2016) with university students as well as the argument in Gottfredson's theory (2002).

Altruistic aspect of perceptions of STEM careers matters

The social value of the careers also seemed to be a major factor in students' consideration regarding both STEM and non-STEM careers, which to some degree echoes Gottfredson's theory that students aged nine to thirteen are very sensitive to a career's social evaluation (Stage 3: Orientation to social valuation). However, the aspect of social value emphasized by the students was not merely about prestige, or the status of the careers, as mentioned in Gottfredson (2002)'s work, but the altruistic value of the career.

The students' altruistic orientation is consistent with the findings in Weisgram & Bigler's quantitative study (2006), in which they found the perception of altruistic values in science predicts students' interest in science. In addition, in students' comments in this study, they seldom rejected a career simply because it has a perceived low social status. Therefore, the orientation of careers for upper-elementary students are different from, but not contradicting Gottfredson (2002)'s theory. The result of the present study can help explain the findings in other empirical studies that show that students of a similar age tend to aspire to careers with higher prestige (Auger, Blackhurst, & Wahl, 2005; Helwig, 2001); the reality, however, may be that students expect to benefit society through their future work in these prestigious careers.

In contrast to Gottfredson's theory (2002), which claimed that the masculinity-femininity orientation is the most significant consideration when making a career choice, none of the students interviewed in this study mentioned this dimension of STEM or non-STEM careers when they discussed their preferred or rejected career options. The result of the interviews also notably differed from Archer et al.'s study (2013), in which 10 to 14-year-old students tended to relate science with masculinity with girls rejecting these careers because they lacked femininity.

Reasons students may lose interest in STEM careers

In this study, one of the most mentioned reasons why students reject becoming a scientist as their career aspiration was due to the expected danger/discomfort of the scientist's work in experiments and research (a kind of negative outcome expectations). This finding resonates with the findings of the qualitative survey as well as previous studies in which features related to danger were shown in students' presentations of scientists (Chambers, 1983; Emvalotis & Koutsianou, 2018; Hillman, Bloodsworth, Tilburg, Zeeman, & List, 2014). The finding of the interviews further revealed that the danger/discomfort aspect of the expected outcomes of being scientists could discourage them from choosing the scientist as a future career.

The interviews also augmented previous studies by showing a new mechanism why some young students reject engineers as a career choice. The results indicate that students' construction of their aspiration to become or reject engineering as a careers choice seemed to be based on their perception that engineering jobs would be exhausting, hot, dangerous, or with too much sun exposure. As indicated by the interviews, these outcome expectations are closely linked to their stereotypical perceptions of engineers, as also uncovered by the qualitative survey. These findings add to previous understandings about students' perceptions of engineers (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Karatas, Micklos, & Bodner, 2011; Liu &

Chiang, 2020) by showing the negative influence of the biased perceptions of engineers.

As found in the interviews, students' perceptions of the task or requirement of STEM careers could navigate their self-efficacy to career interest. In many cases, this navigation is often not biased. However, there are also cases where students may exaggerate the importance of certain efficacy beliefs for some careers. For example, a student may reject scientists as a career option because they are not good at memorizing, which they think scientists will do in their work (as in the case of Lisa). Another example in 4.3 (Nancy) also shows some biased or narrow perception can make the lower self-efficacy of a task the main reason for rejecting a career.

Constructing career interest/goals as a complex process

According to the qualitative survey and the interviews, there are probably different "layers" of perceptions of STEM careers, including instinctive perceptions, which are often stereotypical, visual, superficial (e.g., engineers as builders doing labour work), and comprehensive perceptions, which are more diverse, abstract and complex (e.g., engineers as people doing work related to buildings, including builders who build and designers who design and calculate). However, these instinctive perceptions may easily lead to a rejection of a career as shown in many cases in the student interviews. For example, students may easily reject being a scientist as their career aspirations because of the expected danger of the scientist's work, which is associated with the often-stereotypical image of scientists working in labs doing experiments that may lead to fire, explosions or disease. Students may also easily reject being engineers because of the heat, exhaustion and the expected danger, which is associated with the stereotypical image of engineers working on construction sites.

The results show that the construction process is far-more complex than the SCCT model, which may explain why there have been very few qualitative studies using SCCT as the theoretical framework. One of the merits of SCCT is that it has comparatively clearly defined constructs and quantifiable linear relations among the constructs. However, these are also a weakness of using SCCT in qualitative data. For example, in the students' narrations in this study, the ideas (e.g., perceptions of STEM careers and outcome expectations) are often more blurred and difficult to make distinctions between each other with the way students connect these ideas being diversified and much more complex than linear relations.

6.4.2 STEM stereotypes' effect on career interest through self-efficacy and outcome expectations

The SEM analysis provided evidence indicating that STEM stereotypes have an effect on STEM career interest through the impact on both self-efficacy and outcome expectations. This finding echoes the findings in Garriott et al.'s study (2016) on high school students in which STEM stereotypes had no direct effect on career interest but negatively predicted students' mathematics/science self-efficacy and thus indirectly predicted their career interest. The association (standardized regression weight) between STEM stereotypes and students' self-efficacy in the present study was close to that of the study of Garriott et al. (2016).

The SEM analysis supplements Garriott et al.'s findings (2016) by showing that STEM stereotypes can not only predict self-efficacy but also outcome expectations, which is consistent with the findings in Shen, Liao, Abraham and Weng's study (2014) in which students' self-efficacy, outcome expectations and career interest could be predicted by internalized stereotypes. However, in Shen, Liao, Abraham and Weng's study (2014), internalized stereotypes had direct effects on students' interests in stereotypical occupations, different from the indirect effect in the SEM analysis of the present study. This difference may be due to the distinction between the concept of STEM stereotypes used in this study and the concept of internalized cultural stereotypes used in Shen, Liao, Abraham and Weng's study (2014), indicating the potential difference mechanism of influence between these two different constructs of stereotypes.

The SEM analysis validates the quantitative associations among self-efficacy, outcome expectations and career interest from the integrated STEM perspective. Previous studies examining the SCCT model in STEM usually focused on only one of science, technology, engineering, or mathematics disciplines (Lent et al., 2018). However, there are only a few studies exploring the SCCT model under the STEM integration framework (Garriott et al., 2016; Nugent et al., 2015).

In the SEM analysis in the current study, which is under the STEM integration perspective, self-efficacy in STEM activities significantly predicted students' STEM career interest, which is consistent with the findings in most studies in STEM disciplines (Lent et al., 2018). In Nugent et al.'s study (2015) on students aged 10-14 treating STEM as disciplinary learning, self-efficacy did not significantly predict career goals. In Garriott et al.'s study (2016), high school students' mathematics/science self-efficacy had effects on their mathematics/science career goals via mathematics/science interests. These differences in the direct or indirect effect of self-efficacy on career orientations may be due to the difference in assessment, which is assessing STEM self-efficacy using integrated STEM or disciplinary STEM perspectives, or the different cultural contexts (i.e., Western and Eastern) or age ranges (i.e., upper elementary and high school) of the samples in different studies.

7. Conclusions and implications

This chapter aims to 1) provide a summary of findings and discuss their contributions to the literature; 2) elaborate implications of the findings for the educational community and educational researchers; and 3) analyze the limitations of this study and provide suggestions for future research.

7.1 Conclusions and contributions to the literature

Most students perceived scientists as doing research or inventing using laboratory-related features; engineers as builders, designers or construction site coordinators with features related to building construction; and technologists as doing coding or technical work with technological tools. Students may therefore think scientists' lab work is dangerous and tiring and may thus reject being a scientist as a potential career option. In addition, students may reject being an engineer as a career option because construction work is unpleasant or dangerous. Many students attribute their aspiration/interest in STEM careers to its altruistic value. Finally, negative stereotypes of STEM professionals negatively predict students' self-efficacy in STEM activities and career-related outcome expectations, which in turn influences their STEM career interest.

This study has addressed the research gap in examining students' perceptions of technologists, which is an important type of STEM career. The existence of gender stereotypes of technology, the features of technologists' work and the categories of careers emerging from students' presentations of technologists all add new knowledge to the existing literature. In addition, by examining students' perceptions of technologists along with their perceptions of scientists and engineers, this study provides a more comprehensive view of students' perceptions of several STEM professionals and enables a comparison among them.

This study also addressed the research gap in associating the students' perceptions of STEM careers with their career interest. First, this study provided quantitative evidence to support the notion that STEM stereotypes not only have an impact on career interest through self-efficacy, but also through outcome expectations. Second, the findings provided qualitative evidence that students' perceptions of STEM careers (goals/tasks) may shape their outcome expectations, which could further influence their career interest. Further, students' perceptions of the task or requirement of the career could guide students' self-efficacy to their STEM career interest. These results show how different mechanisms within students' perceptions of STEM careers can have an impact on their career intentions and goals. It is reasonable to have multiple mechanisms as perceptions of STEM careers are more than a single construct or even several constructs but an array of perceptions.

In addition, this study addressed some research gaps related to measurement in STEM education. Some of the instruments used in the qualitative and SEM analysis were newly developed and validated and can be used in future studies in STEM education. First, the qualitative instruments used for investigating students' perceptions of scientists, engineers and technologists can enable educators and researchers to gather in-depth information regarding students' perceptions, especially stereotypical images of STEM professionals. Second, the two checklists developed for analysing the students' drawings and writings about STEM professionals at work can serve as analysing tools in future studies.

Theoretically, this study refined the widely applied model in SCCT by addressing the neglected role of STEM stereotypes, which could shed new light on the theory of SCCT. This study was among the first studies trying to connect students' perceptions of STEM careers with other career-related constructs in SCCT, including self-efficacy, outcome expectations and career interest. The findings in this study could promote a better understanding of the overlapping area of STEM education and career development.

Moreover, the newly developed surveys (STEMaSE, STEMOE and STEMCI) are reliable and valid instruments for quantitative purposes in the measurement of learning outcomes in STEM education. The STEMaSE enables the measurement of young students' self-efficacy in STEM activities. The STEMOE and STEMCI surveys also enable assessment in STEM career-related outcome expectations and STEM career interest from a STEM integration perspective. These measures can also be used to assess the respective constructs and explore many unknown questions in STEM education.

7.2 Implications of findings

The results of this study can serve as a reference for curriculum developers and educators in designing STEM interventions or assessments. There have been various career-related interventions in STEM education applied to elementary or secondary students (Cantrell & Ewing Taylor, 2009; Colston, Thomas, Ley, Ivey, & Utley, 2017; McCann, Marek, & Falsarella, 2016).

The results of the present study suggest that students' biased perceptions of STEM careers are a problem that needs to be tackled, perhaps by providing more accurate information about STEM professionals' work. Specifically, the biased perception of scientists' work being dangerous/tiring and engineers' work being laborious, confined to buildings, unpleasant and dangerous should be tackled. Interventions may consider providing students with introduction of how STEM professionals deal with potential danger/exhaustion in work, the nature of these STEM professionals' work and how diversified these career categories can be. These contents could be conveyed through previously applied approaches in the literature such as by providing students' videos about STEM professionals at work or interviewing them about their work (Colston, Thomas, Ley, Ivey, & Utley, 2017; Wyss, Heulskamp, & Siebert, 2012; Wyss, 2013), inviting STEM professionals to work with students (Barab & Hay, 2001) or giving seminars (Cantrell & Ewing Taylor, 2009).

The results of the study indicate that STEM career information and career-related experiences could be provided to students from various stages of K-12 learning. However, the content of career information and experiences for different grade levels should be different, age-appropriate and well-designed. As Career-related intervention has been proved to be effective in increasing elementary students' career awareness in STEM fields (Colston, Thomas, Ley, Ivey, & Utley, 2017; McCann, Marek, & Falsarella, 2016), the elementary level could be the start point of these career-information-related interventions.

The findings of the qualitative survey of this study showed that, in contrast to the consistency of stereotypes of scientists found in various cultural backgrounds in previous studies, students' stereotypes of engineers in the present study (mostly related to civil construction) were different from the stereotypes found in other cultural contexts in some studies, who were not mostly related to civil construction (Capobianco et al. 2011; Lachapelle, Phadnis, Hertel, and Cunningham 2012). This finding also suggests that some biased perceptions, or stereotypes of engineers could be culture specific. Therefore, educators may need to be aware that students from different cultural backgrounds may hold different stereotypes of some STEM careers.

Some studies have shown that interventions providing students with career information about engineers can increase students' career interest in STEM (Grier and Johnston 2012; Wyss 2013). However, while some other career-related interventions have successfully changed students' perceptions of STEM careers, they did not have a significant influence their career aspirations (Archer, DeWitt, and Dillon, 2014). The indirect impact of STEM stereotypes on career interest found in this study may help explain why this may happen. It is possible that changes in STEM stereotypes alone may not have a direct or immediate impact on students' career interest.

The findings of the interviews and SEM analysis suggest that nurturing students' interest in STEM careers, their perceptions of STEM professionals, the perceived value of their work (career-related outcome expectations), and students' self-efficacy in STEM are very important. The findings of the SEM analysis suggest that one way of intervening on students' STEM career interest is to provide career information and experiences that may eliminate students' STEM stereotypes and nurture their self-efficacy and outcome expectations altogether. To transform the stereotypical image of STEM careers, educators may introduce students to the social-interactive side of STEM professionals, such as showing students how they cooperate with people and reach out to the communities as citizens.

In addition to dealing with students' STEM stereotypes, interventions also need to show students how STEM careers are related to and beneficial to society and thus helping students build positive outcome expectations. Educators may also need to give positive feedbacks on students' own STEM practices to help construct their STEM self-efficacy. According to Bandura (2010), mastery experiences, such as students' successful experiences in STEM activities, could be a major source of STEM self-efficacy for students. Students should be provided with opportunities to know that they are participating in STEM activities and they could succeed in the tasks.

The result of the SEM analysis also highlights the importance of introducing STEM integration into elementary education. The results of the SEM analysis suggest that students' self-efficacy in STEM activities plays an important role in the development of students' interests in STEM careers. Therefore, self-efficacy in STEM activities should be viewed as being important as self-efficacy in mathematics or science disciplinary learning.

In previous studies examining the impact of self-efficacy on career interest/intention in STEM education, the constructs of STEM self-efficacy have been represented by mathematics and/or science self-efficacy (Garriott, Raque-Bogdan, Zoma, Mackie-Hernandez, & Lavin, 2017; Navarro, Flores, & Worthington, 2007; Sahin, Ekmekci, & Waxman, 2018; Wang, 2013) or self-efficacy in STEM as disciplinary learning (Nugent et al., 2015). In the SEM analysis, the survey of STEM self-efficacy did not use the wording of "STEM". Thus, the SEM result shows that engaging in STEM activities has a substantial effect on students' STEM career interest. STEM activities may provide students career-related information and experiences which students can use to develop their self-efficacy and build upon their STEM career interest.

7.3 Limitations and future research

One limitation of the qualitative survey is that the students' drawings may not fully exhibit their "private" perceptions of scientists, engineers, and technologists (Palmer, 1997) but may only show their perceived public recognition of who a scientist, engineer or technologist is, as Losh, Wilke, and Pop (2008) argued. The alternative perceptions were not examined in the qualitative survey; however, the interviews revealed this claim. In future studies, with adequate completion time, the instrument may include several drawing tasks of the same kind of professional, which may enable students to exhibit their alternative perceptions in addition to the stereotyped images.

STEM careers/professionals include more than scientists, engineers, and technologists. Although the researcher assumed that the distinction between "STEM careers" and "scientists, engineers, and technologists" was not very significant, further investigation is needed. As indicated by the first survey collected in the interviews, most students believed that the notion of a STEM career is a broader concept than the concept of being a scientist, engineer or technologist, as it includes more occupation categories.

Another limitation was that neither the qualitative survey nor the interviews explored the factors that can influence students' perceptions of STEM careers. Moreover, how other factors may influence students' STEM stereotypes were also unexplored in the SEM analysis. How students' own demographic factor (gender, age), family background, including socioeconomic status and parental occupations (STEM and non-STEM), and school context may influence students' perceptions of STEM careers; however, this was beyond the scope of the present study, but could be the focus of future research.

There were several limitations to the interviews. First, due to practical considerations, each interview was not long enough to include completion of the survey used in the qualitative survey; therefore, data from the qualitative survey and the interviews was not well-linked. Thus, the chance of full triangulation between the qualitative survey (with drawings and writing tasks) and students' interviews was lost. Second, the sample of interviews participants was limited with regard to diversity, with students from only three elementary schools.

The SEM analysis was limited to the four key constructs in the overlapping fields of STEM learning and career development. Many other individual-level factors, as well as classroom-level, school-level and family-level factors were not included in the SEM model. For example, students' achievement in mathematics or science could also be a influential or outcome factor in the SEM model. In addition, disciplinary

STEM self-efficacy could be added into models in future research to see how much it contributes towards integrated STEM self-efficacy on students' career interest.

Career development is a life-long changing process. The SEM analysis of this study was a cross-sectional investigation which captured an overview of the psychoeducational status of students from the perspective of STEM education and career development. Perceptions of STEM careers, including STEM stereotypes, change with students' learning and other social interactions. In addition, the model in the SEM analysis may vary with other age groups or cultural backgrounds. Future studies may validate the model for older aged students or under other cultural contexts.

Finally, the dynamic interactions of the variables could not be captured by the SEM analysis of the study, although the interviews provided first-person responses explaining the dynamic interactions of the variables. Longitudinal research may better address the question regarding how the variables change with students' age and how the contributing factors may influence the outcome variables.

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Appendices

Appendix 1: Items of drawing tasks and written descriptions of STEM professionals at work in the qualitative survey[6]

- Please draw a scientist[7] at work

  - What is the scientist doing?

    ____

  - The most important task in this scientist's work is to：

    ____

[6] The original items are in Chinese; only items examined as the focus of this study are shown here.

[7] For the sections on engineer and technologist, the word "scientist" is replaced by "engineer" and "technologist" accordingly.

Appendix 2: Work of STEM Professionals Checklist

		Criteria	Emergence (1: yes; 2:no)
Practices	1.	Experimenting	
	2.	Testing	
	3.	Researching	
	4.	Gaining conclusions/ new knowledges/ discoveries	
	5.	Designing (e.g. redesigning, refining design, examining design, testing design, etc.)	
	6.	Making (including assembling)	
	7.	Coding	
	8.	Inventing	
	9.	Examining	
	10.	Fixing	
	11.	Constructing buildings	
	12.	Other specific actions (i.e. moving, mixing, etc.)	
	13.	Supervising others / giving orders	
Features of the work	14.	Creativity	
	15.	Succeeding/making money	
	16.	Connection to the society (e.g. benefiting the society, helping others, etc.)	
Products/ Disciplines	17.	Buildings (the product)	
	18.	Biology/medicine	
	19.	Chemistry	
	20.	Physics	
	21.	Electric/ electronic devices	
	22.	Technology	

Appendix 3: Drawings of STEM Professionals at Work Checklist

		Criteria	Occurrence (1: yes; 0: no)
Appearance and clothing	1.	Explosion hairstyle	
	2.	Sweat	
	3.	Lab coat	
	4.	Glasses/ goggles	
	5.	Masks	
	6.	Safety helmets	
	7.	Suits/ ties/ uniforms	
Emotions and thoughts	8.	Smiling faces	
	9.	Sad faces/ anxious faces	
	10.	Ideas (light bulbs/ Question marks)	
Objects	11.	Test tubes/ flasks	
	12.	Alcohol burners/ fire	
	13.	Bulbs	
	14.	Telescopes	
	15.	Microscopes	
	16.	Planets, stars	
	17.	Plants	
	18.	Animals/ microorganisms	
	19.	Lab desk	
	20.	Experimental machine/ detectors/ incubators	
	21.	Rulers	
	22.	Pens	
	23.	Notebooks (not computers) / papers	
	24.	Robots	
	25.	Computers	
	26.	Mobile phones/ phones/ i-pads	
	27.	Other electronic appliances	
	28.	Contactors/ batteries/ wires/ circuit boards	
	29.	Design drawings	
	30.	Cranes/ derricks/ tractors/ excavators	
	31.	Buildings/ scaffolds	
	32.	Ladders	
	33.	Building materials	
	34.	Spanners/ hammers/ nails/ drills/ welding machines/ toolboxes	
	35.	Automobiles	
	36.	Planes	
	37.	Rockets/ rocket launching	
	38.	Blackboards/ podiums	
Others	39.	Multiple people	

Appendix 4: Example of content analysis of the qualitative survey data

	Analysis 1: the work of STEM professionals checklist (criteria with occurrences were shown)	**Analysis 2: the drawings of STEM professionals at work checklist** (criteria with occurrences were shown)	**Analysis 3: Categorizing the students' drawings of STEM professionals**
 ▪ (The engineer is) **building a skyscraper** ▪ (The most important task in this engineer's work is to) **be safe**	▪ Constructing buildings ▪ Buildings (the product)	▪ Sweat ▪ Safety helmets ▪ Sad faces/ anxious faces ▪ Buildings/ scaffolds ▪ Building materials ▪ Multiple people	▪ Category 3: Construction workers (Doing labor work to build a building)

Appendix 5: Questionnaire A used in the interviews[8]

Please write down the jobs you want to do when you grow up (you may write multiple answers):

____

____

____

[8] The original items were in Chinese; demographic items have been omitted.

Appendix 6: Questionnaire B used in the interviews [9]

Please note the following jobs:

1. Researchers
2. Inventors
3. Construction workers
4. Building designers
5. Construction site coordinators;
6. Technicians (doing installation, repairing etc.)
7. Programmers

Please indicate which of these jobs belong to "scientists" and write down the numbers:

____

Please indicate which of these jobs belong to "engineers" and write down the numbers:

____

Please indicate which of these jobs belong to "technologists" and write down the numbers:

____

Please indicate which of these jobs belong to STEM-related jobs and write down the numbers:

____

[9] The original items were in Chinese.

Appendix 7: Procedures and interview questions

- Procedure:
  a) Introduction of the interviewers, the topic of the interviews and warm-up.
  b) Let students fill in questionnaire A.
  c) Interview students with the following questions (part A) regarding career interest goals and origins.

Interview questions (part A):
1) 1.1 In addition to the jobs you have written down, do you have any other jobs you want to do when you grow up? 1.2 Why do you want to be… (the career that the student has written down or indicated as career goal)? 1.2.1 Since when did you hope to become a/an… (the STEM career students mentioned as career goal)? 1.2.2 What happened at that time that made you think so? Could you tell me more details? ● Do you think these … (activities) resemble the work of … (the STEM career student mentioned)? ● What gives you such an impression that … (the STEM career student mentioned) is like that? 2) 2.1 Have you ever considered to be a … (scientist/ engineer/ technologist/ STEM professional) when you grow up? 2.1.1 (If yes, return to question 1.2)

2.1.2 (If no) Why did you become uninterested? / You don't have interest in becoming a/an … (scientists/ engineer/ technologist), because … ? (may return to question 1.2.2) 2.2 If you become a … (scientist/ engineer/ technologist/ STEM professional), what are the advantages and disadvantages that can you think of? 2.3 What do you think … (scientists/ engineers/ technologists/ STEM professionals) usually do? 3) 3.1 What STEM activities have you participated in when you are at school? 3.2 What STEM activities have you participated in when you are outside of school?

d) Student fill in questionnaire B

e) Interview students with the following questions regarding students' perceptions of STEM careers

Interview questions (part B):
4) 4.1 You think these jobs …. (the careers students written in questionnaire B) belongs to scientists/ engineers/ technologists/ STEM professionals, then overall, what do you think scientists/ engineers/ technologists/ STEM professionals do? Could you summarize scientists/ engineers/ technologists/ STEM professionals' work? 4.2 Are there any other jobs that belong to scientists/ engineers/ technologists/ STEM professionals you would like to supplement?

Appendix 8: Coding scheme for the interview analysis

Codes (only some key codes are shown here)

Code	Label	Definition	Description of how to recognize the code	Exclusion/inclusion criteria	Example (codes are shown in grey background)
P	Perception of STEM careers	Perception of the STEM career itself as a job or the work of STEM professionals OR Perceptions about STEM professional himself/herself	● Usually identified in students' responses about their explanation of questionnaire B, justifications of their career interest or answers about expected outcomes of some STEM careers.	● Perception of STEM careers is descriptive, rather than talking about the students' own expected outcomes of doing such careers. ● Perceptions of STEM careers include content, requirement, purpose/goal of the work, etc.	● ***Interviewer:*** *Could you please help summarize who scientists are?* ***Interviewee:*** *They would use some technological stuff to make something, to program or to make something that benefit others.* [coded as: P (content of work-making)] [coded as: P (content of work-programming)]
SE	Self-efficacy	The perceived capability of doing certain tasks	● Reflected students' confidence/perceived difficulty in doing some tasks, especially the tasks related to a career or relative judgment compared to others.	● Not necessarily directly related to a career. ● Evaluation of a task of being easy/difficult are also included.	● *"**Interviewee:** Because others make electrical equipment or something needs engine on, I think, they may need one or two minutes. I need as much as five minutes. I think (to be) an inventor was not possible."* [coded as: SE (low SE in making)]

Code	Label	Definition	Description of how to recognize the code	Exclusion/inclusion criteria	Example (codes are shown in grey background)
OE	Outcome expectations	Outcome expectations are the expected outcomes of the careers (about anyone who do such jobs)	● The expected, inferred, or imagined outcomes of a certain career. ● Usually following perception of STEM careers. ● Usually identified in students' responses (to questions) about his/her career goals/aspiration or outcome expectation of certain careers	● Including positive and negative outcome expectations	● ***Interviewee:*** *And sometimes (you) need to climb on the scaffolds, which is dangerous. And, and sometimes (you) need to carry mud or something heavy. (**Interviewer:** I see.) So, sometimes I will feel very hot. And I always sweat easily, so I am so afraid I will get sunstroke easily.* [coded as: OE (negative OE)]
CI	Career interest	Students' career interest/goals and its change	● Usually in students' responses (to questions) about his/her career goals/aspiration and follow-up questions.	● Including from aspiring to rejection of careers. ● The change or tendency of change of career interest is also included, e.g. losing interest or growing interest. ● Non-verbal indicators of career interest (e.g. nodding) are also coded.	● ***Interviewer:*** *Have you ever thought about to be a scientist?* ***Interviewee:*** *I have thought about to be a scientist, that is, I would like to be an inventor and help treating others with mental disorders.* [coded as: CI (aspire scientist)]

Themes (only some key themes are shown here)

Theme	Lable	Definition	Description of how to recognize the code	Exclusion/inclusion criteria	Example (Themes are shown in grey background)
P→OE→CI	Perceptions→ Outcome Expectations→ Career interest/goals	Perceptions of STEM careers shape students' outcome expectations, which lead to their career interest and goals	● The student attributed his/her career interest/goals to some expected outcomes of that career which derived from the perceptions of the careers. ● Students may mention it in describing or explaining the development in their career interest/goals (mostly in a retrospective way), in which he/she mentioned about some certain aspect of outcome expectations.	● Subthemes include (not limited to): ✧ Task/goal of STEM careers → positive OE (altruism) → aspire STEM careers; ✧ Task of scientists (experiment/ research) → negative OE (danger/ discomfort) → reject scientists; ✧ Task of engineers (building) → Negative OE (discomfort/ danger) → reject engineers ● P→OE, which does not link directly to certain career interest/goals is not included as a subtheme.	● ***Interviewer:*** *I would like to ask, would you like to be a scientist?* ***Interviewee:*** *A scientist… But I am so afraid that some experiments would make me die, probably.* [Coded as theme: P→OE→CI]

Theme	Lable	Definition	Description of how to recognize the code	Exclusion/inclusion criteria	Example (Themes are shown in grey background)
P +SE→CI	navigation of perception for SE→CI	Students' perceptions of the careers influence students' development of career interest/goals by navigating self-efficacy	● Students attributed their career interest/goals to their self-efficacy on a certain aspect, which is assumed to be important of the career. And that assumption could be derived from students' perceptions of STEM careers. ● Students may mention it in describing or explaining the development in their career interest/goals (mostly in a retrospective way).	● May include explicit navigation (the assumptions about the task/requirement of STEM careers were explicitly stated) and implicit navigation (the assumptions about the task/requirement of STEM careers were not explicitly stated).	***Interviewer:*** *Okay then, have you ever considered to be an engineer in the future?* ***Interviewee:*** *I have thought about becoming an engineer, but I think it will be too tiring.* ***Interviewer:*** *I see, think too tiring and don't want to do that. Why do you think it will be too tiring?* ***Interviewee:*** *Because they may not only need to draw designs but also to be good at math and to calculate how many materials are needed. Only people who are good at math can do that. But my math is not very good.* [coded as theme: P+SE→CI)

Appendix 9: Quantification of some key themes and key subthemes (n=28)

Themes and subthemes		Number of cases	Total occurrences
Theme	P→OE→CI	23	44
Subthemes[10]	✧ Task/goal of STEM careers → positive OE (altruism) → aspire STEM careers	12	18
	✧ Task of scientists (experiment/ research) → negative OE (danger/ discomfort) →reject scientists	7	7
	✧ Task of engineers (building) → negative OE (discomfort/ danger) → reject engineers	7	8
Theme	P+SE→CI	18	27

[10] The subthemes shown in this table are under the theme of "P→OE→CI"

Appendix 10: The items of STEMaSE, MASS[11], STEMOE, and STEMCI survey in quantitative survey for SEM analysis[12]

Numbering	Items[13]
STEMaSE-1	I am able to propose an inquiry (research) question
STEMaSE-2	I am able to design steps of inquiry (research)
STEMaSE-3	I am able to conduct scientific inquiry (research)
STEMaSE-4	I am able to arrange and represent findings of inquiry (research)
STEMaSE-5	I am able to use technological products
STEMaSE-6	I am able to define the problem to be solved
STEMaSE-7	I am able to design solutions to the problems
STEMaSE-8	I am able to test and compare different solutions
STEMaSE-9	I am able to refine solutions
STEMaSE-10	I am able to collect data
STEMaSE-11	I am able to analyze data
STEMaSE-12	I am able to represent the data with graphs
MASS-1	People doing STEM-related jobs are not attractive
MASS-2	People doing STEM-related jobs are weird
MASS-3	People doing STEM-related jobs have poor social skills
MASS-4	People doing STEM-related jobs do not have many friends
MASS-5	People doing STEM-related jobs have bad hygiene
MASS-6	(deleted) People doing STEM-related jobs spend all their time alone
MASS-7	(deleted) People doing STEM-related jobs are not good athletes
MASS-8	People doing STEM-related jobs have a hard time making friends
MASS-9	(deleted) People doing STEM-related jobs always do physical labor
MASS-10	(deleted) People doing STEM-related jobs need to move heavy things, fix and build
STEMOE-1	If I get a STEM-related job, my parents will be satisfied
STEMOE-2	If I do STEM-related jobs, I can help others
STEMOE-3	If I do STEM-related jobs, I can make contributions to society

11 The MASS items were adapted form Math and Science Stigma scale developed by Garriott, Hultgren, and Frazier (2016).

12 The original items are in Chinese; there are instructions for students stating that: "STEM is the acronym for science, technology, engineering and math. People who do STEM-related jobs are people who work in science, technology, engineering, and mathematics jobs, such as scientists, engineers and technologists."

13 The deleted items are marked with "deleted."

Numbering	Items[13]
STEMOE-4	If I do STEM-related jobs, I can make the world a better place
STEMOE-5	(deleted) If I do STEM-related jobs, I can be respected by others
STEMCI-1	I am very interested in STEM-related jobs
STEMCI-2	I hope my future job could be related to STEM
STEMCI-3	My dream career is related to STEM
STEMCI-4	I hope my future job can use STEM
STEMCI-5	I am interested in being a scientist, an engineer or a technologist