Doctoral Dissertation

A Study on the Relationship between Upper Secondary School Track and Post-Secondary Aspiration of Science, Technology, Engineering, and Mathematics (STEM) Majors in Cambodia

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I hereby recommend that the dissertation by Mr. KAO SOVANSOPHAL entitled "A Study on the Relationship between Upper Secondary School Track and Post-Secondary Aspiration of Science, Technology, Engineering, and Mathematics (STEM) Majors in Cambodia" be accepted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY IN EDUCATION.

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Hiroshima, March, 2021

KAO Sovansophal

DEDICATION

With the success of this dissertation, I dedicate this work to my amazing grandmother, *Ngeth Norn*, to whom I owe deep gratitude.

I cherish what she told me: *"Grandson, you must come to Phnom Penh to pursue your higher education. It is good to become a lower secondary school teacher [which does not require bachelor's degree], yet you have even better chances attending university".* With such profound words of business of knowledge, I owe her a lot. What I regret most is that I did not have enough time to pay her back my gratitude, as I should have done.

She who had no education at all. She who loved the knowledge. She who love the truth. And she who will be remembered.

SUMMARY

Introduction: Given the required role of human resources in science, technology, engineering, and mathematics (STEM) to help Cambodia advance during the Fourth Industrial Revolution (also called Industry 4.0) in general, and to help the country achieve economic growth in particular, there is great demand for graduates with STEM majors. However, fewer students are pursuing STEM nowadays. Although interest in STEM is developed and nurtured in upper secondary school, in recent academic years, there has been a worrisome declining number of science track students. Therefore, with the conceptual gap in this context, the main objective of this explanatory sequential mixed methods study is to examine, from a multi-dimensional perspective, factors influencing students' choice of the science track and the effects of tracking as well as other variables that explain Cambodian upper secondary school students' post-secondary aspirations of STEM majors in higher education. To achieve this main objective, three related *Research Questions* guided the investigation:

- *Research Question 1*: What factors are influencing Cambodian upper secondary school students' choice of science track?
- *Research Question 2*: What are the trends and patterns of the time-varying covariates (TVCs) for students who attended in different tracks at upper secondary school for one academic year?
- *Research Question 3*: What are the effects of the tracking system and other variables on Cambodian upper secondary school students' aspirations of STEM majors?

Methods: To answer the research questions, this study employed explanatory sequential mixed method with repeated cross-sectional designs. A self-rated questionnaire containing 28 questions (25 closed-ended and 3 open-ended ones) were used to collect two waves of quantitative data. To explain significant predictors in greater detail, qualitative semi-structured interviews and focus group interviews were conducted online with 25 students. To answer *Research Question 1*, since the outcome variable was coded dichotomously into the science and social science tracks, *Binary Logistic Regression* was employed to analyze the first wave data from a sample of 752 early 11th grade students. Second, *Research Question 2* was addressed through a descriptive lens and some inferential statistics, including independent sample t-test, pair sample t-test, and repeated ANOVA on the two waves of data (waves 1 and 2). Third, to address *Research Question 3*, which aims to measure the effects of

the tracking system and other variables on students' aspirations of STEM majors, the study employed *Hierarchical Linear Model (HLM)* with Bernoulli method to analyze the data of 700 participants from the second wave data (end of 11^{th} grade). As the nature of the study implies, the data from the first wave, first and second waves, and second wave were used to answer research question one, question two, and question three respectively.

Key findings: From the analysis of the data, the study revealed:

- that performance in science and mathematics subjects, attitudes towards science, plan to major in STEM, hours spent self-studying science and mathematics subjects, family encouragement and support, mother's education, and school location significantly predicted upper secondary school students' choice of the science track. Of the 49% of variance explained by the final model, individual factors explained 47% of the variance in Cambodian students' choice of the science track.
- that students perceived science and mathematics outcome expectations, science as a practical subject, and the importance of science in society at a high level. However, they rated science and mathematics self-efficacy, science and mathematics self-concept, interest in science at school, science activities outside school, extracurricular activities in science, future plan in science, support from science and mathematics teachers and interactive science and mathematics lessons at the moderate level. They rated science and mathematics performance as lower than average. Most interestingly, across the span of one academic year, some constructs exhibited increasing trends, yet based on *Cohen's d,* the effect size was at a small level. Moreover, there was a significant negative trajectory for future plan in science and no significant effect for interactive science and mathematics lessons. The patterns also varied across the observations as a function of the covariates of study track, gender, and school location. Notwithstanding, based on the value of *partial* eta^2, the effect size was also at a small level.
- that there is class difference in the upper secondary school students' aspirations of STEM majors. Simply put, 18% of the variance in Cambodian students' aspirations is between classes and 82% of the variance in their choice lies between students within a given class. Specifically, the random-regression coefficients model indicated that gender, academic achievement, future plan in science, and family encouragement and support had an impact. Next, the means-as-outcomes model revealed that students' choice of the science track was not significantly associated with aspirations of STEM majors; however, the interactive science and mathematics lessons were influential.

Discussion:

Key themes for RQ 1:

The effect of academic performance in science and mathematics: A one-unit increase in science and mathematics performance would lead to an increase by a factor of 3.16 in choosing the science track. This implies that performance in science and mathematics contributed to the decline in number of students that choose the science track. Under the strict examination policy whereby *Qualified students can pass (in Khmer: អ្នកចេះគឺជាប់)* students who chose the science track failed the examination at a higher percentage than their peers in the social science. From 2014–2019, on average, about 73% of students in the social science track passed the examination compared to about 49% of students in the science track. While science track students need to take mathematics and all science subjects, students in the social science track only take mathematics and one science subject (usually earth-environmental science). Thus, most of the students swing from science track to the social science track due to their low academic performance in science and mathematics.

Attitudes towards science: Attitudes towards science—as measured on science as a practical subject and future plan in STEM majors—were the second and third most influential factors, respectively, in predicting Cambodian upper secondary school students' choice of the science track. This finding supports the long-held supposition that weaker attitudes towards science and future participation in science are among the factors that reduce the probability of students choosing science or influence students to swing from science. Interestingly, while students should view science as having a practical nature, they might not have been trained to realize the applications of science to their lives in the context.

Family encouragement and support in science: Encouragement and support from family members are critical to Cambodian students' decision-making. The family environment tended to be a significant untapped resource of support for Cambodian upper secondary school students. Further, encouragement and support include not only financial and emotional support, but also the physical space that enables students to have time for studying at school and at home.

Key themes for RQ 2:

Perceived importance, but lower future plan in science: Students' awareness of science and technology in general, and of the importance of science in society in particular, is high. This is a really interesting sign, since according to the Royal Government of Cambodia's national science and technology master plan for 2014–2020, Cambodia has only 17 science and technology researchers and 13 technicians per million of its population. This was due to the fact that Cambodia's social awareness of science and technology is generally low. Although students perceived the importance of science in society, because they might believe that science is difficult and have lower self-concepts in science and mathematics, their future plan in science is low (and even negative) when they move up through the grade levels.

Uneven patterns across the two observations: Although there were increasing trends for some constructs, there was decreasing trend in future plan in science. This might be due to lower self-concepts in science and mathematics and decreasing support from science and mathematics teachers. The small effect of the statistically significant constructs is crucial. Thus, attending in different tracks at upper secondary school for the span of one academic year did not have much of an effect on encouraging students to take science majors at their next level of education.

Study track mattered, yet with a small effect: The effect size increased from the first observation, particularly for science and mathematics self-efficacy, extracurricular activities in science, future plan in science, science and mathematics teachers' support, and interactive science and mathematics lessons. In statistical terms, the effect of the study track was significant, yet small in practical terms. This may indicate a lower effect of attending in different tracks in enhancing the constructs that affect students' uptake from upper secondary school to post-secondary education. There were also significant interaction effects of the observations and study track for some constructs, but not for interactive science and mathematics lessons.

Gender did not matter in early grades, it did in later grades: In the Cambodian context, the public image of the term "science" entails male-dominated jobs. Thus, female students tend to leave science disciplines. This is especially interesting when they move on to higher grades. To a greater extent, this reveals lower interest in (and weaker attitudes towards) science among female students. Further, since science subjects are usually viewed as difficult, and because female students in Cambodian upper secondary school (aged 18–22) usually spend their spare time helping their families (e.g., cleaning and cooking), they might not have enough time to concentrate on such difficult subjects at home.

Key themes for RQ 3:

The importance of interactive science and mathematics lessons, but not tracking: The current study has added to the battery of knowledge to the field by emphasising the effects of how interactive science and mathematics are taught, rather than solely on bifurcating students into different tracks of science versus social science on students' aspirations of STEM majors. Put simply, tracking (increasing the teaching and learning hours, or giving students more time to provide them with greater exposure to science and mathematics courses) does not matter in the Cambodian context. What truly matters is how teachers teach science and mathematics lessons. In other words, simply increasing more teaching hours to science and mathematics but not changing the teaching practices (to the ones which foster the interactions between teachers and students) had no significant influence on students' aspirations of STEM majors in higher education.

The role of gender, academic achievement, motivational belief, and family encouragement and support: Cambodian upper secondary school *female* students are not likely to choose STEM majors in higher education. This finding might be explained by Wiswall et al. (2014), who suggested that STEM majors are characterised by a *"chilly environment"* where female students can feel unwelcome. This finding might extend the literature on the relationship between gender and choice of major, as reflected in Cambodia's cultural reality. Gender stereotypes still exert considerable influence on the decision making process regarding STEM majors, especially when parents are involved.

Another of this study's key findings corroborates results in both Western and non-Western contexts: the positive correlation between students' *academic achievement* in the 11th grade and their aspirations of STEM major at university. Similar results have been confirmed in the Cambodian literature by Eng and Szmodis (2015), Kao and Shimizu (2019), and Eam et al. (2019) and in other contexts such as Lowinger and Song (2017), Shim and Paik (2014), as well as Wang (2013). They claimed that high academic achievement at the pre-university level can impact students' interest and a positive attitudes towards STEM major at university.

Of the four motivational attributes (attitudes towards science and mathematics, science and math self-efficacy, future plan in science, and aspirations to earn a graduate degree) clearly mattered in STEM enrolment (Wang, 2013), this study demonstrated that *future plan in science* have a significant influence on students' choice of a STEM major. This reflects the importance of students' motivational belief on their majors and career aspirations. Those who have clearer plan in science in upper secondary school tend to have greater aspirations in choosing STEM majors in higher education.

Conclusion and implications: After all, the main result of this study could be concluded as follows. The finding from the first study helped explained that the worrisome declining number of students that choose the science track is due not only to individual academic ability and attitudinal variables, but also to cultural influences from family and the condition of upper secondary school. The second study showed that despite the significant influence of different tracks on the time-varying covariates, different tracks had a small effect in improving the constructs that predict aspirations of STEM majors. The effect was negative for students' future plan in science. Consequently, given the small effect, course-taking behaviour between the science and social science tracks in Cambodian upper secondary school did not have any significant association with the students' aspirations of STEM majors in higher education. Instead, their aspirations were influenced by how interactive science and mathematics lessons (in different classes for each respective track) were conducted.

The process leading students to enter STEM fields is complex, as it involves the diverse influences of individual, psychological, contextual, and social factors. Therefore, to address this issue, science and mathematics teachers need to realize that, in addition to enhancing students' academic performance through their teaching practice, one of their ultimate missions is to inspire and deepen students' science self-concept. Also, because the practicality of science subjects matters in one's choice of science track, the most substantial change entails framing the presentation of the material to make science and mathematics lessons (especially starting in early grades) more practical, interactive, and realistic for students. Moreover, learning experiences related to teaching science and mathematics should focus on providing a learning environment with a high level of interaction to propel cognitive activation. Thus, in order for upper secondary school science track to be more effective in promoting students' STEM interest and success, the norms of science and mathematics instruction (for science track) need to be reconsidered. Parents can engage in many school-related tasks to boost their children's science performance and to motivate them to take STEM. Finally, starting in the early grades of secondary education, students should be made aware of how one's choice of track is associated with one's future major and career prospects, so that students have enough information to make a well-informed decision to major in STEM.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

"Science, Technology, Engineering, and Mathematics (STEM) professions create, explain, build, and innovate the world around us. Our nation needs ***STEM graduates*** *to become more competitive in the region and the world, most notably as the country integrates with the ASEAN Economic Community…I encourage Cambodian* ***students*** *to take a strong interest in these subjects, and* ***parents*** *and* ***teachers*** *to support students going into STEM majors" "****STEM majors*** *are driver for Cambodia to achieve the economic development in 2030 and 2050."*

H.E. Dr. Hang Chuon Naron (2016)
Minister of Education, Youth and Sport
Kingdom of Cambodia

CHAPTER ONE: INTRODUCTION

This study aimed to examine factors that explain Cambodian upper secondary school students' choice of the science track as well as the relationship between tracking and other variables on students' aspirations of Science, Technology, Engineering, and Mathematics (STEM) majors in higher education. To understand why it is important to study students' transition from the science track in upper secondary school to STEM majors in higher education, it is vital to grasp the current status and issues surrounding STEM enrolment in Cambodian higher education. This introduction commences with a brief discussion of these themes. The chapter subsequently elaborates on research problems, significance, research focuses, definitions of key terms, and the study's overall organisation. In general, this introduction section gives a snapshot of the entire study.

1.1 Research background

The Royal Government of Cambodia (RGC) has continued to prioritize *capacity building and human resource development* as the first growth rectangle of the Rectangular Strategy Phase IV (RGC, 2018). The strategic goal of the RGC is to develop a quality, equitable, and inclusive education system by focusing on science and technology, labour market orientation, and physical education to support national socio-economic development. In compliance with this strategy and to ensure consistency in terms of hierarchy, coherence, and synchronisation with National Strategic Development Plan (NSDP) Updated 2019–2023, and the Industrial Development Policy 2015-2025 of the Royal Government of Cambodia (RGC, 2019a), Ministry of Education, Youth and Sport (MoEYS) launched its Education Strategic Plan (ESP) for 2019–2023, with a continued focus on two medium-term education policy objectives: (1). Ensure inclusive and equitable quality education and promote life-long learning opportunities for all and (2). Ensure effective leadership and management of education officials at all levels (MoEYS, 2019a).

In responding to the strategic objective of the Rectangular Strategy, as the effect of the first policy objective of ESP, there has been a dramatic increase in the number of students enrolled in higher education sector. According to the statistics compiled by the Department of Higher Education (DHE), enrolment rose from 14,778 in academic year 1998–1999 to 179,258 in the academic year 2018–2019 (MoEYS, 2019b).

From the perspective of economic growth, Cambodia has traditionally been an agricultural society and agricultural development has always been given priority to reduce poverty and strengthen rural development. However, after being admitted into the Association of Southeast Asian Nations (ASEAN) in 1999 and becoming a member of the World Trade Organization (WTO) in 2004, in addition to agriculture, the RGC has come to focus on three additional pillars: garments, tourism, and construction. Recently, the Fourth Cambodian Economic Forum on "The Cambodian economy in post-crisis environment: Industrial development policy options toward a sustainable economic development" strongly emphasized the strategic vision of the RGC in shifting the country's economic growth from dependence on agriculture, garments, tourism, and construction to a broad-based industrial, technology-oriented economy to help the country to become a higher-middle income nation by 2030 and a high-income state by 2050 (RGC, 2015; 2018; 2019b).

Science, Technology, Engineering, and Mathematics (STEM) disciplines, without question, are crucial to maintaining the country's global competitiveness. STEM fields are receiving national and international attentions, as they are the foundation for partnerships and alliances in the global economy. In this sense, post-secondary education is necessary to achieve desired levels of competency and efficiency in STEM fields (Means et al., 2018; Moakler Jr & Kim, 2014; Owens, Shelton, Bloom, & Cavil, 2012; Wang, 2013). The demand for graduates in STEM fields around the world has risen at a relatively rapid rate. Cambodia is no exception. As stated, one of the primary aims of the RGC's Rectangular Strategy Phase IV is to *strengthen and enhance education, science and technology and technical training* to support Cambodia's new economic growth during the Fourth Industrial Revolution (also called Industry 4.0) (RGC, 2013, 2018). In line with this, human resource in STEM fields is vital. STEM graduates create, explain, build and innovate the world around us. Thus, Cambodia needs more young people who are skilled and qualified in these subjects to develop the Kingdom human resources, economy, and to drive its development. The nation critically needs STEM graduates to become more competitive in the region and the world, most notably as the country integrates into the ASEAN Economic Community. Science and technology will be indispensable to the government's New Growth Strategy and Cambodia's long-term vision (British Embassy, 2016; RGC, 2015, 2018). According to the Cambodia Development Resource Institute (CDRI, 2015) and the Japan International Cooperation Agency (JICA, 2016), in order to maintain the country's gross domestic product (GDP) growth of 6% – 8% between now and 2020 Cambodia would need about 35,000 engineers and another 46,000 technicians. Furthermore, as reported by the National Employment Agency (NEA, 2018), the number of employment opportunities for graduates in technical and scientific realms is very high and expected to increase significantly. To serve industrial needs, this is true not only for those who have a lot of experience but also for fresh graduates. From a broader perspective, based on a survey by the World Economic Forum (WEF) on employment opportunities from 2015–2020, conducted in 15 developed and developing countries, in fields such as architecture, engineering, and computer science human resource will be in great demand in the coming year during Industry 4.0 (CDRI, 2015; WEF, 2018).

Accordingly, MoEYS developed its *Science, Technology, Engineering, and Mathematics (STEM) Education Policy* (MoEYS, 2016a). The policy emphasized that since Cambodia is a developing country with a growing economy, its inhabitants need to be encouraged to explore the demand for 21st–century skills and thus produce more human resource in STEM fields in order to move the economy forward. However, to be more competitive in the region and in the world, Cambodia still has a great demand for graduates in STEM fields (Asian Development Bank [ADB], 2011; RCG, 2015; Un & Sok, 2016; UNESCO National Education Support Strategy [UNESS], 2010). Consequently, MoEYS, as stated in the ESP for 2014–2018, politically aims to increase overall enrolment in STEM fields in both public and private higher education institutions (MoEYS, 2014a). Notwithstanding, according to the statistics compiled by DHE and MoEYS, the share of students enrolling in these fields remains low. In short, according to the CDRI (2015) and MoEYS (2017), despite higher market demand—which is likely to transform and modernise Cambodia's industrial sector by 2025—not many students are enrolling in STEM-related fields, but rather non-STEM fields.

To address this issue, several initiatives have been implemented. In order to train competent professionals in science and mathematics in upper secondary school and to provide more guided pathways for choosing academic majors in higher education, MoEYS implemented a tracking system in 2010 (MoEYS, 2010). This bifurcation system requires all 11th grade students to choose either the science or social science track. While the former focuses on mathematics and science subjects (physics, chemistry, biology, earth–environmental science), the latter centres on Khmer literature, history, geography, and moral civics. Statistically, since the beginning of its implementation, the science track has drawn more students than the social science track. As shown in Figure 1.1, of the 84,934 upper secondary school students in

2014–2015, more than 87% chose the science track while only 12% chose the social science track (MoEYS, 2019c).

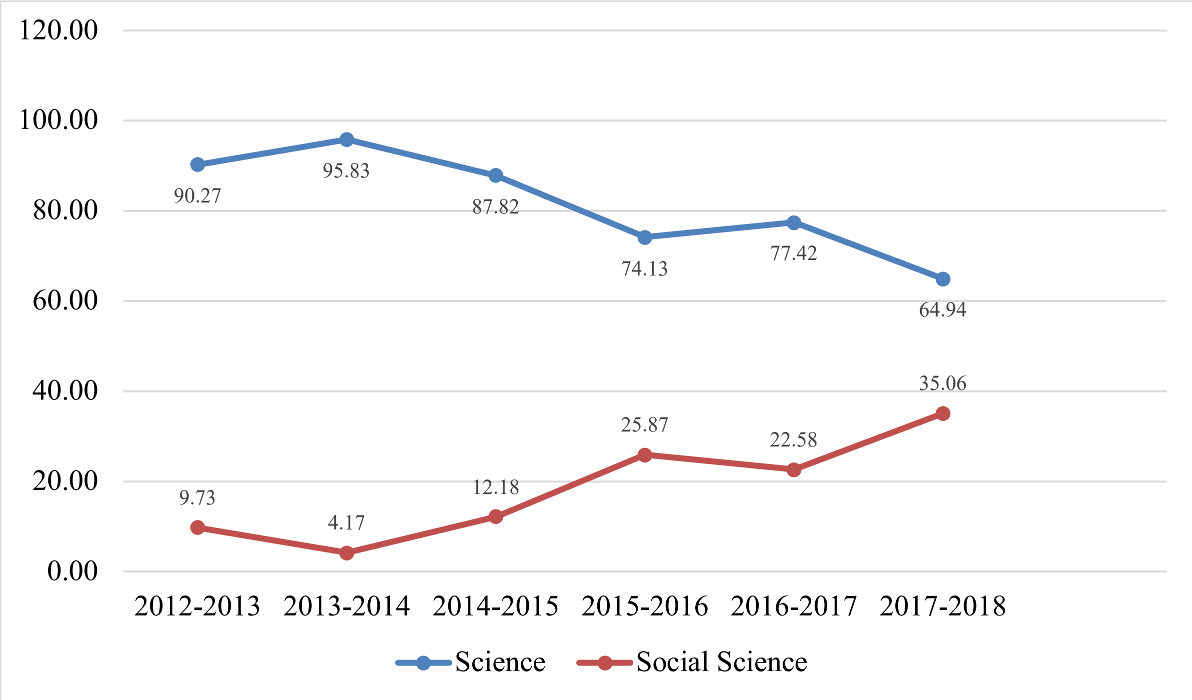


Figure 1.1: Percentage of students in the science and social science tracks in Cambodia' upper secondary schools

Source: Statistics compiled by Department of General Education from 2011–2019, MoEYS (2019c)

Nevertheless, the situation is currently changing dramatically. Although MoEYS aims to increase the number of science track students in upper secondary school so as to expand enrolment in science and engineering related in higher education, the number of Cambodian students choosing the science track—which is a crucial foundation to develop students' STEM aspirations in higher education—has shown a worrisome declining trend. According to MoEYS statistics, in the academic year 2017–2018, the percentage of Cambodian students choosing the science track dropped significantly, from more than 87% to about 65%, while the proportion of students in the social science track jumped from about 12% to about 35% (MoEYS, 2019c). More critically, of 100,776 students, the number of those in the science track has worrisomely continued to decline to about 49% in the academic year 2018–2019 and this figure continues to shrink. This negative trajectory is of great concern for MoEYS in trying to enhance science and mathematics education at upper secondary school in particular, and STEM enrolment in higher education in general.

1.2 Research problem

The Cambodia Development Resource Institute (CDRI, 2018) reported that while the number of those enrolled in higher education institutions rose from 13,461 to 179,256—or from 1% in 1996 to 13.3% of the youth-aged cohort in 2019 (MoEYS, 2020a)—only 27% majored in science, technology, engineering, and mathematics (STEM). In post-graduate courses, less than 10% of students major in STEM, which highlights the imbalance in students' majors and the mismatch with the share of those in the science track at upper secondary school level (ADB-ILO, 2015). In line with this, JICA (2016) further emphasized that the lack of STEM-related graduates is hindering the diversification and modernisation of Cambodia's industrial structure in trying to achieve economic growth by 2030 and 2050.

To transform Cambodia from a lower-income to a higher middle-income country, it is crucial to improve the skills of the existing workforce and those who are prepared to enter the workplace. Through this mechanism, the number of low-skilled workers would be reduced, while the low number of medium and highly-skilled workers would rise (RGC, 2017; Un, 2012). In this regard, there is a greater need for medium and highly-skilled STEM graduates (JICA, 2016). Consequently, although MoEYS has aimed to increase the enrolment in STEM fields to 32% by 2023 in order to respond to the Industrial Development Policy (IDP) and the Rectangular Strategy phase IV of the RGC (MoEYS, 2019a), a lower percentage of students in STEM remains a main obstacle in MoEYS achievement plan for 2014–2018 (RGC, 2019a).

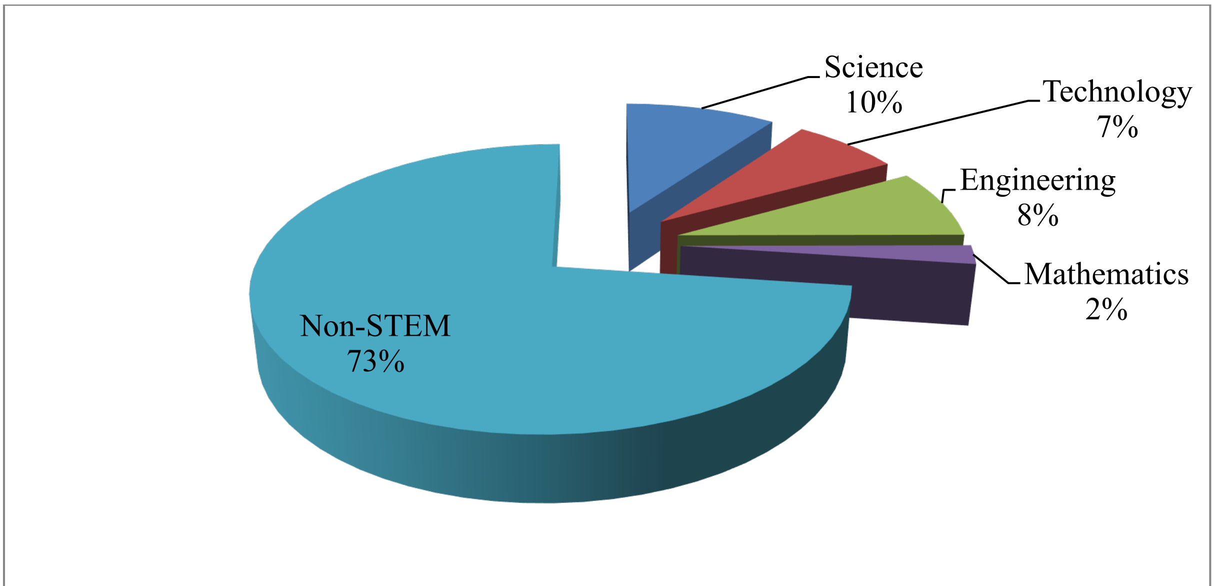


Figure 1.2: Share of graduates in STEM and non-STEM related majors from 2017–2018
Source: Statistics compiled by DHE, MoEYS (2019d)

However, more seriously, as can be seen in Figure 1.2, there is an imbalance between the share of those enrolled in STEM and non-STEM fields. While the upper secondary school level has experienced an alarming-decline in the proportion of students in the science track, Cambodia's higher education level has faced mass enrolment in (and oversupply of graduates in) non-STEM fields such as business, management, economics, humanities, and accounting (comprising more than 70% of total enrolment) (MoEYS, 2019d). This indicates an unsettling drop in students' interest in, and attitudes towards science from upper secondary school to STEM in higher education.

For decades, concerns have mounted among policy makers and researchers with respect to the decline of students' interest in science and their decision to study science/STEM majors worldwide (e.g., Kinyota, 2013; Li & Kuan, 2018; Myeong & Crawley, 1993; Paik & Shim, 2013; Shim & Paik, 2014; Zuniga, Olson, & Winter, 2005). In particular, researchers have sought to understand the root causes of the drop in science enrolment and in scientific literacy (Han & Buchmann, 2016; Kinyota, 2013; Myeong & Crawley, 1993; Shim & Paik, 2014; Shimpkins, Price, & Garcia, 2015). This is no exception in the Cambodian context. Low enrolment has a significant impact on the need for human resources in supporting Cambodia's current phase of economic development and has given rise to the quest among educators and scholars to understand students' choice of major in higher education (e.g., CDRI, 2018; Eam et al., 2019; Eng & Szmodis, 2016; Kao & Shimizu, 2019; Pen, 2011; Peou, 2017) as well as how upper secondary school tracking influences one's choice of majors in higher education. However, until recently, none of the studies have extensively examined, at the fundamental level of upper secondary school students' choice of track (science versus social science). Little is known about how variables such as individual ability and attitudes, family background and encouragement, and upper secondary school experience and support contributed to explain Cambodian students' choice of the science track and how it affects students' academic aspirations in STEM majors in higher education. The paucity of empirical evidence as such is surprising given the decrease in the number of students in the science track, and the growing demand for STEM graduates in the developing context like that of Cambodia in the Industry 4.0 era.

Upper secondary school has been considered as a critical period for attracting students to science, as it is significantly correlated with their post-secondary educational choices of major and career interest in STEM (Dustmann, 2004; Kier, Blanchard, Osborne, & Albert, 2014;

Kinyota, 2013; Lee, Min, & Mamerow, 2015; Li & Kuan, 2018; Maltese & Tai, 2011; Seymour & Hewitt, 1997; Shim & Paik, 2014; Shimpkins et al., 2015; Stearns et al., 2016; Unfried, Faber, Stanhope, & Wiebe, 2015). It is at upper secondary school that students' academic choice making in STEM is developed and nurtured. In addition, as some researchers (e.g., Myeong & Crawley, 1993; Paik & Shim, 2013; Welch, 1985) maintained, students' choice of the science track is one of the much-needed research areas within respective context to investigate the students' aspiration of STEM majors in higher education. Therefore, the main purpose of the current study is ***to investigate factors that explain Cambodian upper secondary school students' choice of the science track and the relationship between the tracking system and other variables that explain their aspirations of STEM majors in higher education.***

1.3 Rationale and significance: Responding to the research problem

This current study endeavoured to understand Cambodian upper secondary school science outcomes in STEM majors. Basically, this study scrutinized the correlates among one's choice of the science track, the trends and patterns of time-varying covariates (TVCs) of students in different tracks, and the association between one's choice of science track and other multi-dimensional factors on Cambodian upper secondary school students' aspirations of STEM majors in higher education. While some prior studies have handled the problem in certain ways, the present study is unique in its own critical respects.

- First, the findings from this study contribute significantly to the understanding of the theoretical gap identified in the extant literature in Southeast Asian countries, as well as in the Cambodian context. Because the conceptual framework was built from a multi-dimensional perspective, the current study can provide a comprehensive look into science outcomes (the aspirations of STEM majors) uniquely among Cambodian upper secondary school students.
- The study is also unique in its methodology; it is the first study to undertake a panel investigation of the upper secondary school students' aspirations of STEM majors in higher education in Cambodia. Further, since the study was conducted under the pragmatic philosophical view, the explanatory sequential mixed method nature provides a holistic, insightful landscape for explaining Cambodian students' choice of the science track and its relationship to their aspirations of STEM majors in higher education.

Practically, in response to the discussion of the research problem described above, this current study is likely to contribute to the process of developing human resources in STEM majors as well as promoting the relevancy of Cambodia's higher education sector. The following points highlight such functional and academic contributions.

- The question of how Cambodian upper secondary school students choose their majors and why they choose them remains unanswered in most schools and higher education institutions. Due to the unavailability of adequate information and effective help, many students may have difficulty in determining their choice of track and majors. This can be a great waste of resources and time for students, institutions, and MoEYS. Hence, results of this study could inform policymakers by offering implications for DHE and the DGE (of MoEYS) for future policy initiatives, in order to guide upper secondary school students regarding their choice of majors and to ignite their interests in STEM-related fields.
- The results also provide some guidelines for policy action at upper secondary school level to help students in term of track selection, major, and career plan. Eng and Szmodis (2015) and Nugent, Barker, Welch, Grandgenett, and Nelson (2015) highlighted an imminent need for additional major and career preparations for students who are about to graduate from upper secondary school.
- The effects of different tracks at upper secondary school in improving students' outcomes (especially science outcomes) are understudied. Hence, the results would contribute to practical knowledge of how different choices of tracks influence students' science outcomes. Consequently, this will provide suggestions for effective measures that could be applied to boost students' science outcomes at upper secondary school and their aspirations of STEM majors in higher education.

1.4 Research focus: Purpose, questions, and objectives

1.4.1 Research purpose and main questions

The main purpose of this explanatory sequential mixed method study is to examine the effect of tracking and other multi-dimensional variables that explain Cambodian upper secondary school students' aspirations of STEM majors in higher education by holistically conceptualising diverse dimensions of personal ability and attitudes, family support, and school-enabling conditions. Therefore, the study basically tried to answer two main questions:

What factors influence Cambodian upper secondary school students' choice of science track? and are upper secondary school science track and other variables influencing Cambodian upper secondary school students' aspirations of STEM majors in higher education?

1.4.2 Specific research questions

To achieve the aforementioned main purpose and main questions, the current study could be viewed as a combination of three related minor studies. That being said, the specific purpose of this study was to answer three related *Research Questions*:

- ***Research Question 1:*** What factors (individual, family, and school) are influencing Cambodian upper secondary school students' choice of science track?
- ***Research Question 2:*** What are the trends and patterns of the time-varying covariates for students who attended in different tracks at upper secondary school for one academic year?
- ***Research Question 3:*** What are the effects of the tracking system and other variables on Cambodian upper secondary school students' aspirations of STEM majors?

Simply put, *Research Question 1* focuses on the factors that explain the students' choice of science track at upper secondary school from the three dimensions of individual input, family, and school support. *Research Question 2* centres on the trends and patterns of the time-covarying variables across the period of two repeated measurements as a function of gender, school location, and study track. *Research Question 3* focuses on the effects of tracking and other multi-dimensional variables (individual, family, and school) on students' aspirations of STEM majors in higher education. This question aimed to determine whether the students' choice of the science track had a significant association with their aspirations of STEM majors, net of the other dimensional variables, and the effects of the other factors that explain students' aspirations of STEM majors in higher education. This last question responds directly to the main purpose of the current study.

These three research questions are related from two perspectives. From a practical perspective, the aforementioned research questions are coherently connected in such a way that, to investigate the relationship between tracking and other multi-dimensional variables that influenced students' science outcomes in majoring in STEM majors *(Research Question*

3), it was logically necessary to delve deeply into the trends and patterns of the time-varying predictors variables across the two observations as a function of gender, school location, and study track *(Research Question 2)*, and fundamentally the factors that explain the students' choice of the science track at upper secondary school *(Research Question 1)*. RQ1 also aimed to determine if future plan in science is associated with students' choice of science or social science track. Theoretically, the three research questions logically linked together under a multi-dimensional framework, conceptualised from the four theoretical and conceptual models that explore the factors explaining the students' choice of STEM majors in the international and local context. After all, this study takes an explanatory sequential mixed method approaches as it strives to answer the questions of *"what factors"* and *"why"*.

1.4.3 Specific research objectives

The specific research objectives herein elaborate the focused aspects of the data analysis that ultimately answer each of the three research questions. Each research question was specifically scrutinized based on the features of quantitative trends, quantitative patterns, and qualitative explanations.

Research Question 1 focuses on investigating upper secondary school students' choice of science track. The objective of the first research question was to quantitatively identify the factors from the three dimensions (individual, family, and school) that explain the students' decision to enrol in the science or social science track at upper secondary school. Quantitative Binary Logistics Regression analysis of the individual dimension, family dimension, and school dimension variables that significantly explain this association was one of the key methodological objectives of the current study. Follow-up interviews were conducted to provide further qualitative explanations for the significant factors revealed by the quantitative data analysis.

Research Question 2 focuse on orientation of individual students towards STEM majors. In specific terms, the objective of this research question was to measure the quantitative level of time-varying covariates (e.g., students' attitudes towards science, self-efficacy, and family encouragement and supports), as well as general and particular trends (e.g., students' attitudes towards science, self-efficacy, and encouragement and support). Another sub-objective of this question was to investigate the patterns of these variables across individual and institutional demographic variables (the relationship between science outcome orientation variables and repeated measurements as a function of gender, school location, and study track). That is to say, the objective of research question 2 was to present the quantitative trends of indicators, and the quantitative patterns of relationships between indicators and the individual, family, and institutional demographic variables through a descriptive lens.

Research Question 3 focuses on investigating the effects of choosing the science track and other variables (individual, family, and school) on upper secondary school students' aspirations of STEM majors. Hence, the objective of this research question was to quantitatively measure and investigate if there was any significant association between science track and students' aspirations of STEM majors. The specific objective was to discover the variation in aspirations of STEM majors when students were nested in different tracks and classroom practices and to thus identify its association with the students' aspirations of STEM majors from a multilevel analysis, specifically the Hierarchical Linear Model. In the same sense as research question 1, follow-up interviews were conducted to provide a deeper understanding of the significant predictors revealed in the quantitative investigation.

1.5 Originality of the study

The study was designed and conducted to fill the gap in the literature on promoting students' interest in majoring in STEM in higher education, so as to meet the need for human resource for Cambodia's new trend of economic development. To the best of researcher's knowledge, this study is the first of its kind to discern the factors that explain Cambodian students' aspirations of STEM majors prospectively from the science track at upper secondary school. This study, thus, aims at introducing a novel perspective for reconsidering the important aspects of various factors, with the ultimate goal of expanding enrolment in STEM majors from the upper secondary school to higher education nexus.

1.6 Definitions of terms

This study contains numerous terms that frequently used, and to help clarify their use, they deserved to be defined below. This section offers explanations based on theoretical or practical definitions, and elaborates on how the terms were defined in the current study so as to strike a balance between theoretical benchmarks and practical feasibility.

- ***Science, Technology, Engineering, and Mathematics (STEM):***

  There is no globally accepted definition of STEM education or an approach to STEM integration (English, 2016). Yet, the acronym STEM—which was introduced by National Science Foundation (NSF) in 2001 to refer to science, technology, engineering, and mathematics curriculum—has gained considerable momentum since then (Breiner et al., 2012). Later, the NSF came to employ STEM as an acronym for broad fields of study in higher education (Green, 2007; Sanders, 2009). By the same token, the current study, thus, adopted the STEM acronym to represent a certain group of majors in higher education. Broadly speaking, ***STEM majors*** include not only the common categories of mathematics, the natural sciences, engineering, and computer/ information science, but also social/behavioral sciences such as psychology, economics, sociology, and political science. However, many recent efforts have aimed to improve STEM education, mainly in mathematics, natural sciences, engineering, and technologies. For this reason, this study excluded social/behavioral sciences from STEM majors. Thus, STEM majors included mathematics, natural sciences (including physical sciences and biological/agricultural sciences), engineering/engineering technologies, and computer/ information sciences (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Chen, 2013; Chen & Weko, 2009; Crisp et al., 2009; Green, 2007; Maltese & Tai, 2011; MoEYS, 2009, 2016b, 2020c; NCES, 2020; Ulicna & Royale, 2015; Wang, 2017; Wang & Lee, 2019). On the other continuum, non-STEM fields in this study, included social/behavioral sciences, humanities, business, education, economic, management and others (Chen, 2013; MoEYS, 2009, 2016b, 2020c; Ulicna & Royale, 2015; Xie, Fang, & Shauman, 2015). See the list of STEM majors in Appendix 1.

- ***Tracking:***

  For decades, studies have claimed that early track choice could have important consequences for future academic trajectories and labour market outcomes (Darolia, Koedel, Main, Ndashimye, & Yan, 2018; Dustmann, Puhani, & Schönberg, 2017; Kerr, Pekkarinen, & Uusitalo, 2013; Li & Kuan, 2018; Lucas, 1999; Myeong & Crawley, 1993; Oakes, 1986). Although studies have defined tracking in various ways (Gamoran & Mare, 1989; LeTendre, Hofer, & Shimizu, 2003), this study adopted the ground-breaking definition of tracking by Oakes (1986), which refers to the process whereby students are divided into categories so that they can be assigned (in groups) to various kinds of classes. Put simply in the context, it is the process whereby Cambodian upper secondary school students are placed in the different tracks of *science* and the *social science* for their 11th and 12th grade education. Due to a recent education reform, the new generation school (NGS), now only offers the science track to students which is divided into subject focused class of chemistry, physics, biology, computer, and mathematics.

- ***Aspiration(s) of STEM majors:***

  In this context the term refers to students' initial choice of major that they strongly desired for. It entails the intension to pursue a STEM degree in higher education. This is the so-called initial choice for one's major and career, as in this process, students will determine which major to pursue in higher education and the potential career that they can work in after graduation.

- ***New Generation School (NGS):***

  As an extension of the Child Friend School (CFS) programme at a much higher standard, NGS started to open in 2016. The schools were aimed to create a new development track within the public education system that would lead to the creation of *autonomous public schools (school in a school),* which receive high investments linked to new standards of accountability and governance as well as professional standards for 21st—century learning. A key objective of NGS is to improve teaching standards through novel approaches that include competitive teacher recruitment, performance-based incentives, intensive capacity-building in educational technology, STEM and problem-based learning methodologies, and explicit teacher career paths linked to professional development opportunities. NGS requires increased hours of instruction to provide access to special subject themes that may focus on STEM subjects where students can specialize in physics, chemistry, and biology (MoEYS, 2016c).

- ***Science outcomes:***

  The major outcome variable of this study includes students' aspirations to major in science, technology, engineering, and mathematics (STEM). The other supportive indicator is the subscale that measures students' future plan in science.

- ***Repeated measures:***

  Repeated measures encompass surveys with more than one times measure with the same samples. For this study, the researcher carried out two waves of data collection with the same group of students: at the beginning and at the end of 11th grade—to collect baseline data (first observation) and to see how attending a different track in

11th grade affected the students' science outcomes—end of grade 11th (second observation). Six months transpired between the first observation and the second one. There were two main justifications for setting this span. First, the period was consistent with the Cambodian academic calendar. Although the school calendar started on 01st November and ended on 31st August, a greater number of students are usually absent in the first and the last months. Also, the total time period was designed in accordance with the researcher's academic calendar at the university.

1.7 Limitations of the study

The interpretation of the results of this study could be done in light of the following methodological limitations. First, the academic majors in this study were the aspired majors students intended to pursue in higher education, not the actual majors they are doing at the time of the study. In other words, the majors here refer to the intended majors 11th grade students were applying rather than the final ones. Notwithstanding, this is consistent with social cognitive career theory (SCCT) in which the behaviour can start with an initial choice and a final choice (Lent, Brown, & Hackett, 2002). Second, due to time and budget constraints, the samples for this study were not very big compared other cross-sectional studies conducted elsewhere that addressed a similar issue. Third, the academic achievement used in this study was the readily available score, averaged from the targeted school norm-referenced semester tests scores. The researcher was unable to formulate the test items, which could have covered all science and social science subjects, but would have consumed much more class time to conduct the tests. The diversity of scoring from school to school was also a concern. Nevertheless, the obtained score was standardized into a *z*-score before carrying out further analysis. Next, despite the fact that the predictive relationships in this current research were modeled using an advanced and sophisticated software, the conclusion does not imply any causality of the relationships embodied in the data. No causality should be inferred from this study. The experimentation of specific variables would be suggestive of confirming cause-and-effects relationships. Last but not least, the study explains the factors influencing upper secondary school students' aspirations of STEM majors in higher education predominantly based on quantitative data from the questionnaire survey, which were measured by multi-item psychometric scales. Research that wholly investigates the issue qualitatively is needed to gain greater insight into effective teaching and learning practices for the science track at upper secondary school and their relations with students' aspirations of STEM majors.

1.8 Research ethics

Because this study has a repeated cross-sectional nature, personal data about the sampled students was gathered. To guarantee research ethics, the study took the following measures. First, researcher sent the permission letter from the Department of Higher Education requesting for permission to conduct the field research study to get approval from the targeted schools. The survey was conducted after receiving the authorization from each school. Second, since the study also collected data on the students' academic achievement, the researcher obtained approval from the school principals as well as from each student that participated. In this token, the researcher asked the students to voluntarily sign the informed consent forms. The study excluded questionnaires from the students who did not sign it. Thus, participation was completely voluntarily. Students who voluntarily participated in the first and the second waves of data collection could drop out at anytime. Also, the researcher gave the students a 10-minute instruction on the purpose, the how, and the possible benefits they might gain from this study before they completed the survey questionnaire. Fourth, to keep track of the selected samples, the study used name tags with personal information as the cover page of the questionnaire (please refer to Appendix 2). After the researcher coded the questionnaire, the name tags were then removed from the questionnaires, and confidentially kept in a safe envelope so that no personal identity of the participating students could be recognised. Fifth, the dataset was kept secured and accessed by only the researcher and only used for the current study.

1.9 Structure of the dissertation

The whole dissertation is segmented into eight chapters. Each chapter discussed on related topics. *Chapter One* highlights the problem, the significance, and purposes of the research, and presents the coherence of the study's three research questions and how they were investigated. It also defines several important key terms to facilitate readers' understanding. *Chapter Two* proceeds to discuss and synthesize the extant theoretical foundations of students' enrolment into higher education in general, and the theoretical and conceptual models for students' choice of STEM majors in higher education in particular. This chapter aims at drawing the conceptual constructs and dimensions to be employed in the current study. *Chapter Three* begins with an overview of Cambodia's general and higher education as well as recent reforms, especially on science education enhancement so as to increase students' probability of choosing a STEM major. The later section of the chapter reviews pertinent related literature in both developed and developing nations. The chapter specifically discusses the literature from the viewpoint of the conceptual model synthesized and elaborated in the previous chapter. Chapter three ends with the conceptual framework of the current study. *Chapter Four* explains in overall on the question of *"how"* the study was conducted including the sampling process, research instrumentation, data analysis, analytical tools and so on. It concludes with tables indicating data analysis method by specific research objectives as well as the analytical framework of the current study. The next chapters, *Chapter Five, Chapter Six,* and *Chapter Seven* covers the main findings on the correlates of choice of the science track, the trends and patterns of the time-varying covariates across time, and the effects of tracking and other multi-dimensional variables on Cambodian upper secondary school students' aspirations of STEM majors respectively. Simply put, while chapter five and six present the findings, discussion, and conclusion to research question one and research question two respectively, chapter seven outlines the results, discussion, and conclusion of research question three—the main research question. These chapters follow a structured writing style: the main question, a brief method (samples and data analysis), results, discussion, and concluding remarks. Last, *Chapter Eight* further delves into the key findings responding to the main research questions and the research problem mentioned in the introduction chapter. The chapter ends with a final conclusion and implications for how the research problem could be solved. Figure 1.3 below portray the graphical structure of this dissertation.

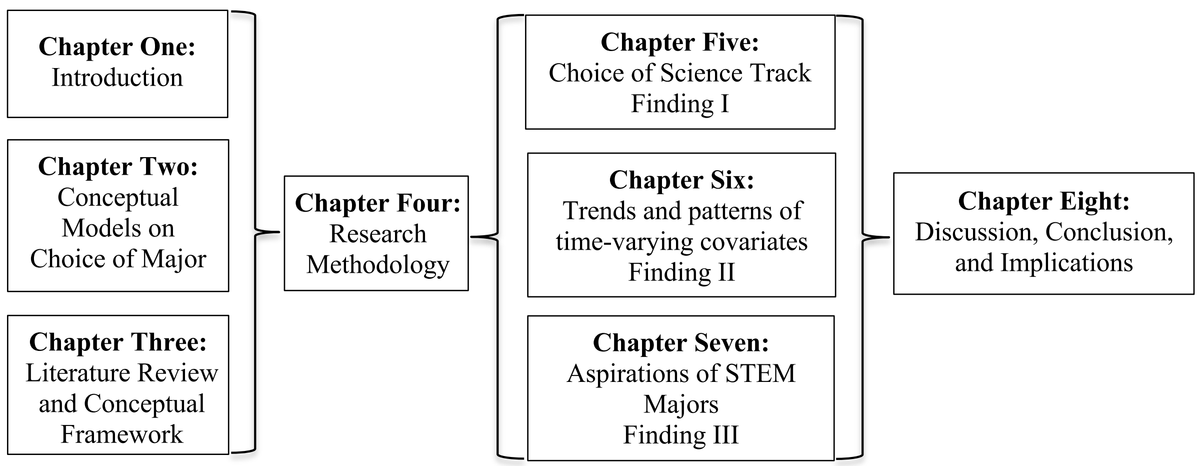


Figure 1.3: Graphical structure of the dissertation

CHAPTER TWO: CONCEPTUAL MODELS FOR CHOICE OF ACADEMIC MAJOR

This chapter synthesizes the extant theoretical foundations of students' choice of majors in higher education general, and theoretical and conceptual models for students' choice of STEM major in particular. The chapter begins with the bigger theoretical foundations of students' choice of major in higher education, then proceeds to the nuances of the models employed to investigate one's choice of STEM major in higher education. The chapter concludes with a synthesis of the discussion on the conceptual models, and draws on the dimensions and constructs covered in the conceptual framework of the current study.

2.1 Theoretical orientation

2.1.1 The theoretical foundations for one's choice of majors in higher education

This study employed three vital theoretical foundations to understand the students' choice of major in higher education: Holland's vocational choice theory, rational choice theory, and human capital theory. First, *Holland's vocational choice theory*, a combination of psychological and sociological components, argues that students choose study fields based upon their own personality type: realistic, artistic, investigative, social, enterprising, or conventional (RAISEC) (Furnham, 2001; Holland, 1959; Holland, 1966). People with different personality types possess different attitudes, interests, and competencies. The salient difference between Holland's vocational choice theory and the psychological perspective on decision-making is that Holland's theory connects individual personalities with the environment in which people find themselves. People do best in an environment where their competencies, skills, and interests are valued, and preferred activities are rewarded (Arnold, 2004; Hogan & Blake, 1999; Holland, 1959). Moreover, when making a vocational choice, a person is the product of the interactions between his/her unique heredity and various cultural and personal forces, including parents and the physical environment. Similarly, the theory links psychological factors (e.g., students' personality types) to create a model of *person-environment fit* that can be used to explain students' selection of academic majors in college (Smart, Feldman, & Ethington, 2000). Both psychological and sociological interpretations of Holland's theory are significantly needed to grasp students' expectations and experiences (Pike, 2006). Positively, because its emphasizes the interactions between individuals and the environment, Holland's vocational choice theory has been widely adopted for investigating students' choice of major and occupation among certain student populations, such as those at selective liberal arts colleges (Arnold, 2004; Furnham, 2001; Porter & Umbach, 2006). Despite considerable applicability, Holland's theory does have limitations. Leong, Austin, Sekaran, and Komarraju (1998) asserted that students' other demographic characteristics including socio-economic status (SES) might also have a bearing on students' choice of major. In this regard, the influence of these factor—as well as possible interactions between person-environment congruence and educational, social, and economic factors—should not be ignored when examining the mechanism underlying one's choice of college major. Nevertheless, these aspects have been the pitfalls of Holland's theory (Nui, 2017).

Secondly, while Holland's vocational choice theory is rooted in a psychological perspective, *rational choice theory* stems from economics and sociology. As such, rational choice theory maintains that individuals act *rationally* by calculating the costs and benefits of an action before deciding what to do (Scott, 2000; Sianou-Kyrgioy, 2010). Individuals are motivated by their own *preferences*, yet, also acted within given *constraints*. They make decisions in relation to both their preferences and the means for reaching their goals. At the simplest level, since it is impossible for individuals to achieve various things they desire, they must also make choices in relation to both their goals and the means for attaining them. Hence, individuals must anticipate the outcomes of diverse courses of action and calculate one which will be best for them (Hechter & Kanazawa, 1997; Scott, 2000). Rational choice theory has been applied in educational research to scrutinize students' decision-making process and the different types of participation in higher education among students of varying social classes (Nui, 2013). Individuals anticipate the outcomes of alternative options in choosing their majors and determine the one that will benefit them the most. Rational individuals choose the alternative that is most likely to give them the greatest satisfaction. Despite this power, the term "rationality" is not defined by that theory. Therefore, the meaning has been left open to interpretations, which may lead to doubt about validity of the theory in explaining students' behaviours, and about its application in research on students' decision-making process (DesJardins & Toutkoushian, 2005; Nui, 2013).

Thirdly, although Holland's vocational choice theory and rational choice theory focused on the *psychological* angle and the rationality of different *individual preferences* as well as *personal and environmental constraints* on decision-making, respectively, social and economic factors that represented personal and environmental constraints remained unexplained (Nui, 2013). *Human capital theory*, formulated by Schultz in the 1960s (Blaug, 1976), argues that individuals and society derived economic benefits from investing in higher education (Olaniyan & Okemakinde, 2008; Scott, 2000; Sweetland, 1996; Van der Merwe, 2010). Parents strongly feel that in today's era of high demand for skilled manpower, the better the education their children could get, the better are their chances of getting a well-paid job. Moreover, in the process of investing in getting a better education, social constraints relative to individual characteristics—such as gender, age, ethnicity, family composition, and socio-economic status (since they determined one's position in society)—played an inevitable role in students' decision-making process (Brown, 1995; Bucher, 1979; Nui, 2017; Sianou-Kyrgioy, 2010; Van der Merwe, 2010). Thus, personal preferences and competencies are not the only determinants of decision-making. These environmental constraints necessitated the investigation of students' choice of major from a sociological and economic standpoint. The returns of a college education that individuals receive depend heavily on factors such as their family background, demographic characteristics, and even the features of the college they attended (Nui, 2013; Olaniyan & Okemakinde, 2008). Family income is thus one of the most important factors in students' educational choices.

The aforementioned theoretical foundations are primarily grounded in three approaches: (1) the social psychological perspective, (2) sociological status attainment, and (3) economic approaches. While the social psychological perspective centres on the influences of the environment and the person-environment fit, the sociological status attainment approach focuses on the impact of students' social background. The economic approach relies on human capital theory to model students' decision-making impacted by the rational behaviour of financial considerations. The study utilized these three approaches to determine the theoretical and conceptual models for students' choice of STEM majors. Consequently, the study derived four main conceptual models—(1) students' choice of academic major model, (2) the making of engineering and scientists model, (3) social cognitive career theory, and (4) the STEM transfer model—which were employed as the framework to identify the constructs to be investigated in the current study.

The three theoretical foundations are coherently associated with the four theoretical and conceptual models from two critical angles. First, understanding the mechanism underlying the students' decision-making process requires careful consideration of students' preferences and social background, environmental constraints, and educational contexts. Despite that in

Holland's vocational choice theory, personal preferences, attitudes, interests, and competence play a pivotal role in students' decision-making process—at a time when access and equity in higher education are yet to be achieved—some students might not be able to afford to make decisions based on personal interests and preferences. Other factors might be more pressing and weigh more heavily on their considerations of their educational choices. As a result, human capital theory and rational choice theory provided a framework for exploring such factors from an economic perspective. Costs or benefits alone do not determine people's choices; rather, it is the balance between the two that play a substantial role. The notion that students make decisions within contextual constraints recognises the complexity of students' reality, which goes beyond personal preferences and places students in layers of factors (including cultural constraints and educational context) that might have bearing on their educational choices. Consistently, overall, the constructs in the four theoretical and conceptual models also fall within the multi-dimensional aspects of individual inputs, cultural influences from one's family, and support in the education setting (the next section outlines the details). Therefore, the theoretical foundations as well as the theoretical and conceptual models indicate the impact of multi-dimensional factors on students' choice of academic majors. Secondly, the study employed the three theoretical foundations, as well as the four theoretical and conceptual models, to investigate the students' choice of majors in higher education in general, and their choice of STEM majors in particular. While the synthesis of the former emphasizes the effects of students' preferences and social background, environmental constraint, and educational setting, the synthesis of the latter underscores the impact of individual inputs, cultural influences from one's family, and the support in the education context on students' choice of major.

2.2 Theoretical and conceptual models for choice of STEM major

The literature has adopted a number of theoretical and conceptual models investigating students' choice of STEM major. Based on the previously discussed theoretical foundations on one's choice of major in higher education, the theoretical and conceptual models for STEM enrollment behaviour tend to vary from motivational psychology, to individual behaviour, to contextual and social behaviour (Lowinger & Song, 2017; Seymour & Hewitt, 1997; Wang, 2013; Wang & Lee, 2019). The following sections discusses the four theoretical models that have gained much attention and that have been empirically employed in the studies on students' choice of science and engineering or STEM majors in higher education.

2.2.1 Students' choice of academic major model

Based on the concept that one's choice of academic major is a key tenet of both the market economy and a democratic society, this decision involves matching and combining individual goals with one's social role (Hu, 1996). Likewise, the model for students' choice of academic major classifies the decision-making process into two main stages: the initial choice and final choice. The initial choice of college majors is influenced by predisposition (upper secondary school achievement, socio-economic status, parental income, educational aspirations, etc.), school attributes (school and class size, geographical location, etc.), significant others, financial aid, one's perception of economic factors, and perceived quality of the programme involved (Hu, 1996). As a consequence, predisposition, perceived quality of the programme, school attributes, and one's perception of economic factors will procedurally affect the students' final choice. Synthesised with the components from the work of Hossler, Braxton, and Coopersmith (1989), the students' choice of academic major model integrates the variables into four dimensions: the econometrics model, sociological model, consumer model, and combined models. For instance, the students' views of economic benefit are drawn from the econometrics model, while college experience and educational aspirations with different socio-economic status are derived from the sociological model. Satisfaction of self-fulfillment for personality is developed based on the consumer model, with multiple stages and a dynamic process, and the availability of information in the process of decision-making is in line with the combined model (Hu, 1996). Contextually, the model has been utilised to examine upper secondary school students' choice of major (Pen, 2011) and students' choice of science and engineering majors in higher education (Kao & Shimizu, 2019). However, the use of this conceptual model in relation to repeated investigations remains to be researched in the context.

2.2.2 The making of engineers and scientists model

To scrutinize the factors that affect the students' choice of science and engineering majors in higher education, a model for the making of engineers and scientists was developed in 1994. Based on this model, the development path of students' choice of science and engineering majors is influenced by individual inputs (e.g., student potential, ability and personality), school factors (e.g., school type, curriculum), and external input (e.g., parental advices, institutional initiatives) (Woolnough, 1994a; Woolnough et al., 1997). Put simply, the essential dimensions of the model's variables include individual inputs, family environment, and school supports. In 1997, the model was employed as a framework for a large-scale, parallel study on factors that influence students' choice of career in science and engineering in Australia, Canada, China, England, Japan, and Portugal (Woolnough et al., 1997).

Overall, the model posits that students who transition from the upper secondary school system to higher education in science and engineering are significantly influenced by their scientific home background. This includes not only their attitudes towards science, but also their technical hobbies and skills. Second, from the angle of school support, the teaching practices of science and mathematics teachers at upper secondary school matter regarding the students' choice of science and engineering. There is some evidence that the future scientists prefer a student-centered approach to a more structured, teacher-directed one (Woolnough, 1994a, Woolnough et al., 1997). Practically speaking, the importance of both the quality of science teachers and extracurricular activities in science is of the concerns when encouraging students to major in science and engineering career choice (Woolnough, 1994a, Woolnough et al., 1997). In sum, the making of engineers and scientists model covers the three crucial aspects of students' potential (personal input), school factors, and so-called external input (family and society). Although the model has not been wisely used, the transitional nature from upper secondary school to higher education nexus, as well as the consistency with human capital theory, enhance the applicability for the current study.

2.2.3 Social cognitive career theory (SCCT)

The most fundamental theoretical model, SCCT, has often been employed in research on students' choice of STEM major (e.g., Ekmekci, Sahin, & Waxman, 2019; Fouad & Smith, 1996; Lee, Min, & Mamerow, 2015; Lent et al., 2018; Maltese & Tai, 2011; Moakler & Kim, 2014; Navarro, Flores, & Worthington, 2007; Ruse & Xu, 2018; Sahin et al, 2017; Usher & Pajares, 2009; Wang, 2013; Wang & Lee, 2019). SCCT rooted from the Social Cognitive Theory of Albert Bandura's general social cognitive theory (SCT; 1986), and highlights the interplay between self-referent thought and the social process in guiding human behaviour. SCCT is cyclical in nature and longitudinal in scope (Lent, Brown, & Hackett, 1994); it has been immensely heuristic, finding application in a wide range of psychosocial domains including education, health, management, and affective reactions (Bandura, 1986). SCCT is also linked to the two branches of career inquiry that evolved from Bandura's general framework: Krumboltz's social learning theory of career decision-making (Krumboltz, 1979) and the self-efficacy construct for women's career development by Hacket and Betz (1981). Although SCCT was built on the conceptual foundation of Krumboltz's theory, it is closely aligned with the self-efficacy construct by Hackett and Betz (Lent, Brown, & Hackett, 2002). However, SCCT shares Krumboltz's emphasis on the learning experiences that shape people's occupational interests, values, and choices; and acknowledges the influence of genetic factors, ability, and environmental conditions in decision-making.

To illustrate the interacting influences among people, their environment, and behaviour, SCCT contains a bidirectional model of causality of personal attributes (internal cognitive and affective states and physical characteristics), external environmental factors, and overt behaviour. In conceptualising personal determinants, SCCT, incorporates three crucial variables from general Social Cognitive Theory (SCT)—(1) self-efficacy, (2) outcome expectations, and (3) personal goals—as the basic building blocks (Lent, Brown, & Hackett, 2002). First, self-efficacy concerns with one's capability to perform a given task (the mentality of "I can do it"). Self-efficacy is acquired and modified through four primary sources: (1) personal performance accomplishment, (2) vicarious learning, (3) social persuasion, and (4) physiological and affective states (Bandura, 2010; Hackett & Betz, 1981). Secondly, outcome expectations are personal beliefs about the consequences of performing a particular activity or behaviour. According to Lent et al. (2002), outcome expectations consisted of extrinsic reinforcements (receiving tangible rewards for performing a task successfully), self-directed consequences (pride in oneself for mastering a challenging task), and outcomes derived from the process of completing a given activity. Some scholars claimed that outcome expectations—which are acquired through learning experiences and probably influenced by self-efficacy—played a vital role in motivating behaviour. Thirdly, a goal may be defined as the determination to engage in a specific activity or to influence a future outcome (Bandura, 1986; Lent et al., 2018).

By and large, SCCT entails a complex interplay of goals, self-efficacy, and outcome expectations in the self-regulation behavior (Bandura, 1986). For example, self-efficacy and outcome expectations affect the goals one selects and the efforts expended in one's pursuit of them. In return, personal goal influence the development of self-efficacy and outcome expectations. Put simply, people form goals to sustain or increase their involvement in a particular activity when they develop an affinity for, for which they are efficacious and expect positive outcomes (Lent et al., 2002; Lent et al., 2018). The goals increase the likelihood of engaging in the particular activity. Also, along with self-efficacy, outcome expectations promote particular goals for engaging in the activity. The achievement obtained from performing it produces crucial feedback that reshapes self-efficacy and outcome expectations, and in turn, interest in the activity.

Lent et al. (2002) further asserted that SCCT assumes that the basic process is constantly in motion throughout the lifespan, and that through this process, people develop patterns of interest in a certain major. Most noteworthy, whether new interests emerge depends less on exposure and past reinforcement experiences, and more on how people perceive their self-efficacy and their prospective expectations. In addition, SCCT acknowledges that ability and value are important parts of the vocational interest. However, the effects primarily occur through self-efficacy and outcome expectations. SCCT also accounts for other individuals and contextual influences such as gender, race/ethnicity, physical health or disability, genetic endowment, and socio-economic conditions (Lent et al., 2002; Wang, 2013) that could influence the social cognitive variables and to the career development.

In sum, SCCT (which is rooted in social cognitive theory [SCT]), revealed the influences of self-efficacy, outcome expectations, and interest in choosing a goal. Notwithstanding, since the theory is not established in a vacuum, several other factors are also taken into account. For instance, personal input (predisposition, gender, race), background contextual affordances, and learning experience stemming from Krumboltz's social learning theory have also been positioned in the theoretical model of SCCT.

2.2.4 The STEM transfer model

Lastly, in integrating Social Cognitive Career Theory (SCCT) with the extant literature, Wang (2013, 2017) came up with a theoretical model for STEM majors—the STEM transfer model—which stresses the secondary and post-secondary context in determining the students' choice of STEM major. Put simply, the model hypothesizes that students' intention to major in STEM is affected by their 12th grade mathematics achievement, their exposure to science and mathematics courses, and science and mathematics self-efficacy beliefs. In turn, all of these variables are influenced by prior achievement in (and attitudes towards) science and mathematics. On the other continuum, entrance into STEM fields is also impacted by post-secondary contextual supports and barriers. To be specific, while post-secondary supports includes not only academic interactions but also financial aid, college readiness in mathematics and science, academic aspirations, and enrollment intensity; post-secondary barriers encompass remediation, and external demands from one's family (Wang, 2013, 2017; Wang & Lee, 2019).

Although a number of studies on choosing a STEM major have applied SCCT, and SCCT is supposedly a valid explanatory framework, such research is largely limited by cross-sectional and single institution data (Lent et al., 2010). The model for choice of STEM majors stresses the importance of early mathematics and science experiences, which are vital for future plan in STEM education (e.g., Adelman, 1999, Kao & Shimizu, 2019; Lowinger & Song, 2017; Moakler & Kim, 2014; Trusty, 2002). Thus, mathematics and science learning at upper secondary school, mathematics achievement, and exposure to science courses are linked to the students' intention to later specialize in a STEM field. Most noteworthy, these three elements are shaped by early mathematics achievement and attitudes, especially in light of the longitudinal and developmental nature of achievement in (and attitudes towards) science and mathematics (Eccles, 1994; Trusty, 2002). In addition to SCCT, the modified STEM transfer model includes not only the early preparation (e.g., attitudes towards mathematics and science in grade 10^{th} and mathematics achievement), but also the exposure to science and mathematics and secondary and post-secondary contextual supports.

2.3 Synthesis of the four theoretical and conceptual models

Numerous theoretical and conceptual models have been employed to investigate students' choice of major in STEM in higher education. As framed by theoretical foundations of one's choice of major in higher education, the study analyzed and synthesized the previously described four theoretical and conceptual models. As consequent, Figure 2.1 presents a synthesis of them so as to draw the conceptual framework that provides the lens of investigation in the current explanatory study. In a broad sense, this synthesis illustrates the crucial dimensions and variables underlying each dimension. The study synthesized the variables in order to give a holistic view of the variables. By and large, the study extracted and then classified the constructs of each conceptual model into the multi-dimensional variables of personal or individual input, family influence, and school support. From an empirical angle, Chapter 3 (which contains the literature review) comprehensively covers the constructs listed under each dimension.

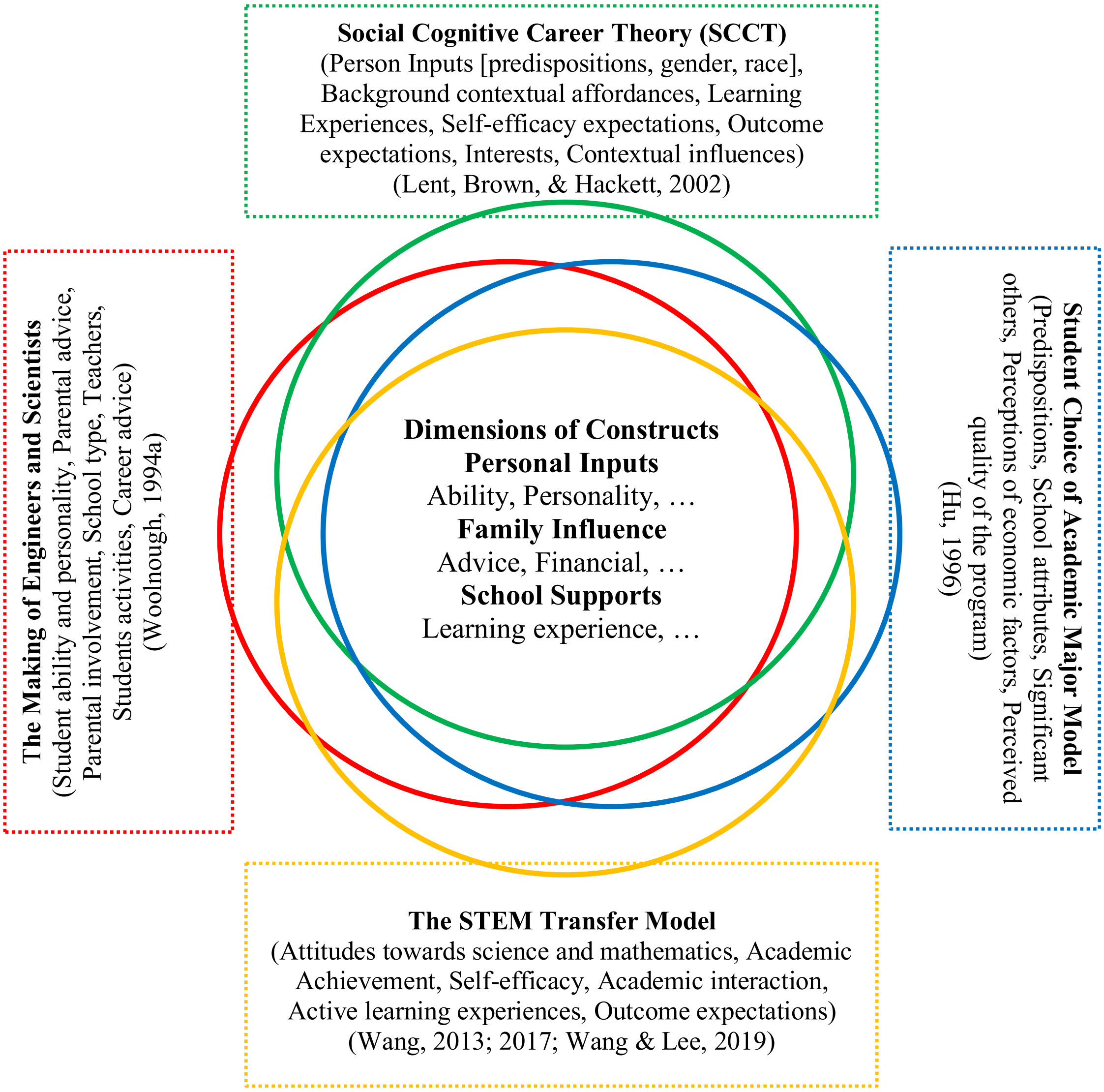


Figure 2.1: Synthesis of the conceptual models for choice of major in STEM

CHAPTER THREE: LITERATURE REVIEW

This chapter provides an overview of general education and higher education as well as detailed discussions of factors that empirically explained the students' choice of STEM majors. The chapter begins with brief summary of modern general education and higher education in Cambodia and the country's educational structure, followed by the academic transition from upper secondary to higher education, and the admissions system into higher education. The chapter then describes the tracking system, its form and types, and delves into the global and contextual perspectives on the empirical evidence for students' choice of STEM majors. Further, in synthesis with the initiatives implemented by several developed countries in promoting students to major in STEM, the chapter elaborates on the evidence-based variables as both time-invariant predictors and time-varying predictors, based on the multi-dimensional variables through the lens of the synthesized conceptual model. The chapter concludes with a recap of the literature to direct the reader toward the conceptual framework, as well as the indicators and their measurements.

3.1 Cambodia's general education system

To understand a single educational problems without having grasped its broader context is somehow misleading. Hence, this section examines the development of Cambodia's education system in general and higher education in particular. After its reform from 1996–1997, the nation's formal educational structure is formulated based on a "6+3+3" configuration. This means it takes 12 years to complete one's general education: six years of primary school (1^{st}–6^{th} grades) followed by six years of secondary school (7^{th}–12^{th} grades). Secondary education consists of three years of lower secondary school (7^{th}–9^{th} grades) and three years of upper secondary school (10^{th}–12^{th} grade). (See Appendix 6 for details.)

Primary school is the first level of education in Cambodia. The curriculum is divided into two three-year cycles (1^{st}–3^{rd} and 4^{th}–6^{th} grades). Children from the age of six are eligible to enter. The purpose of the basic education curriculum (1^{st}–3^{rd} grades) is to ensure that every child has a strong foundation in literacy and mathematics and that children develop their health, physical appearance, moral understanding, learning skills and life skills. In the first cycle, pupils study the Khmer language (13 hours/week), mathematics (7 hours/week), science and the social science (including arts; 3 hours/week), physical and health education (2 hours/week), and local life skills (2–5 hours/week). In the second cycle (4th–6th grades), the students expand and consolidate their knowledge and understanding of the Khmer language, mathematics, learning skills, life skills, moral, and personal development, this enables them to pursue life-long learning, and they are exposed to content in science and social studies. Students need to study 6 or 7 subjects for a total of 27–30 hours per week (MoEYS, 2004; 2006). See Table 3.1.

Table 3.1: Distribution of subjects and hours of study for grades 4th through 6th

No.	Subject	Grade		
		4	**5**	**6**
1	Khmer	10	8	8
2	Mathematics	6	6	6
3	Science	3	4	4
4	Social studies (+Arts)	4	5	5
5	Foreign language		*	*
6	Physical and health education	2	2	2
7	Local life skills	2-5	2-5	2-5
Total weekly hour		**27-30**	**27-30**	**27-30**

Note: * Implemented based on the capacity of each school

Moreover, secondary education lasts for 6 years. This level is divided into lower secondary (7th–9th grades) and upper secondary (10th–12th grades) (RGC, 2007). The purpose of lower secondary school curriculum is to provide students with a breadth of knowledge of the Khmer language, mathematics, sciences, social studies, life skills, learning skills, vocational education, moral civics, and personal development; this allows them to become productive members for the growth of Cambodian society, to further their studies in the upper grades, to participate in other vocational trainings, and to participate in social life (MoEYS, 2004). At the end of 9th grade, students take a national examination leading to a diploma of lower secondary education. The examination covers 10 subjects including the Khmer language (composition and dictation), mathematics, physics, chemistry, biology, history, geography, earth-environmental science, moral civics, and a foreign language (either English or French). Students are given an overall passed grade of grade A (Good), B (Fairly good), or C (Average). Individual subject results are not announced for the grade 9th examination (MoEYS, 2019e).

The second cycle is from grade 10th to 12th. The purpose of grade 10th curriculum is to expand and consolidate students' knowledge obtained in lower secondary school. In addition, schools must ensure the provision of a significant subject choice advice for students to study in grade 11th and 12th. The career advice provision must start from the beginning of the school year. Consequently, grade 11th and grade 12th curricula aim to give students the opportunities for: increased specialization by freely choosing a subject to develop an in-depth knowledge of particular subjects or to take training-based vocational classes in order to continue on to higher education, to study vocational subjects, or to participate in their social lives (MoEYS, 2004). The grade 12th examination covers 6 compulsory subjects and 1 lucky-draw selective subject. In the science track, students take mathematics, physics, chemistry, biology, Khmer literature, English or French, and one lucky-draw selective social science subject. However, students in the social science track take Khmer literature, mathematics, history, moral civics, geography, English or French, and one lucky-draw selective science subject. Students are awarded an overall grade of A (Excellent), B (Very good), C (Good), D (Fairly good) or E (Average) and percentile rank. Individual subject results (Grades A–E) are also shown (MoEYS, 2020b).

3.2 Cambodian higher education

According to Clayton and Yuok (1997) and Sam et al. (2012), due to the pressure from the West and diminishing support from the (now former) Soviet Union, Vietnam withdrew its occupation forces from Cambodia in 1989, leaving behind a fragile yet functioning government. In terms of higher education, the period between the Vietnamese withdrawal and the United Nations (UN)-supervised election in 1993 was particularly difficult for Cambodian higher education. Along with troops, Vietnamese educational advisors and professors returned back to Vietnam, and Soviet professors left shortly after the Soviet Union collapsed. As a result, in some cases, higher education institutions employed fresh Cambodian graduates as lecturers. In other cases, some higher education institutions were forced to close. For example, the Agricultural Institutes was forced to close briefly in 1990, and the Khmer-Soviet Friendship Higher Technical Institute might have closed if no teachers had returned from the Soviet Union in 1991 (Ayres, 1999, 2000). This phenomenon has also affected the the current landscape of higher education enrolment in general and in science and engineering-related majors in particular.

Consequently, during the transition from 1991–1993, because the government retained control over the existing educational administration, there were few changes conducted by

United Nations Transitional Authority in Cambodia (UNTAC). The shift may have occurred in 1994 when the government, together with international development partners, developed the National Program to Rehabilitate and Develop Cambodia (NPRD), in which human resource development was a key pillars (Clayton & Yuok, 1997; Sam et al., 2012). With the introduction of policies on public-private partnerships (privatization) in higher education in 1997 (Pit & Ford, 2004; Un & Sok, 2018), the number of HEIs rose from 18 in 1997 to 125 in 2019 (Mak, 2012; MoEYS, 2019d). Currently, these number of HEIs can admit a net enrollment of about 13.3% of the youth-age cohort (RGC, 2017; MoEYS, 2020a) and produce graduates to reasonably serve the country's economic development needs. However, this figure should be expanded to increase access to higher education learning and to diversify the nation's economic development in the knowledge-based economy. Along with the dramatic increase in the number of HEIs, the enrolment in the sector increased remarkably from about 14,778 in the academic year 1998–1999 to about 179,258 in the academic year 2018–2019 (MoEYS, 2018a; MoEYS, 2019b).

3.2.1 The structure of Cambodia's higher education system

The current Cambodia's higher education landscape, with a total of 125 higher education institutions and their respective provincial branches, is governed by 16 government agencies (MoEYS, 2019a; see Table 3.2 for details). Surprisingly, although there are many so-called "parent ministries" or agencies, a single governing authority or designated body has yet to coordinate them all, especially in the areas of national education policy formulation, implementation, and monitoring (Sen & Ros, 2013). To some extent, this cause Cambodia's higher education into a fragile system.

Table 3.2: Higher education institutions and their supervising ministries

No.	Supervising Ministry	Public	Private	Total
1	Ministry of Education, Youth and Sport	13	63	76
2	Ministry of Labour and Vocational Training	12	14	26
3	Ministry of National Defence	5	0	5
4	Ministry of Culture and Religion	3	0	3
5	Ministry of Agriculture, Forestry and Fisheries	3	0	3
6	Ministry of Health	2	0	2

7	Ministry of Culture and Fine Arts	1	0	1
8	Ministry of Interior	1	0	1
9	Office of the Council of Ministers	1	0	1
10	Ministry of Public Works and Transport	1	0	1
11	National Bank of Cambodia	1	0	1
12	Ministry of Social Affairs, Veterans and Youth Rehabilitation	1	0	1
13	Ministry of Mines and Energy	1	0	1
14	Ministry of Posts and Telecommunications	1	0	1
15	Ministry of Economy and Finance	1	0	1
16	Ministry of Land Management, Urban Planning and Construction	1	0	1
	Total	**48**	**77**	**125**

Source: MoYES (2019a)

With the number of higher education institutions and the emphasis on equitable access in higher education policy, more students are pursuing higher education degrees. As outlines in Figure 3.1, about 168,242 students were pursuing a bachelor's degree in the academic year 2017–2018. The past few academic years have witnessed a decreasing number of students enrolled in higher education compared to the number of upper secondary school students. This declining trend resulted from the reform of the national grade 12th exit examination. Chhinh, Edwards, Williams, and Yu (2015) pointed out that the recent policy reform of the national exit examination at upper secondary school has focused on the strong efforts of the RGC to eliminate and/or to stop irregularities such as cheating, and the leakage of examinations. With a strict examinations policy, only 40% of students were capable of passing the national exit examination, compared to the passing rates of approximately 80% in the past decade (MoEYS, 2014b). Apart from the strict examination policy, the 2014 termination of the policy to use the academic achievement from semester 1 and 2 to add onto the baccalaureate examination score may have contributed to this phenomenon. However, the percentage of the students passing the examination has risen in the most recent academic years to about 64%, 66%, and 70% in 2017, 2018, and 2019, respectively (MoEYS, 2019d). On the other continuum, the increase in this enrolment reflects not only the importance of higher education based on the perception of the general public, but also the improvement of the quality of the students (specifically the rise in the share of the students who passed the grade 12th national examination) in the general education system due to education reform.

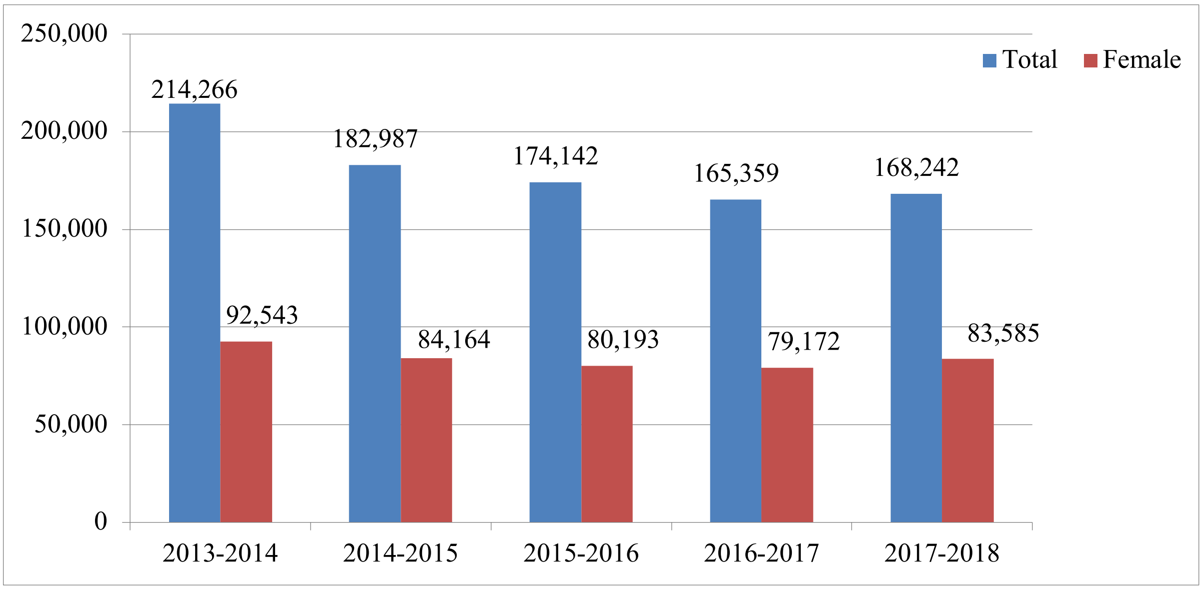


Figure 3.1: The number of students enrolled in bachelor's degree programmes in Cambodia

Along with the expansion of students' enrolment in higher education, in order to temporarily deal with the oversupply of graduates in non-STEM fields (e.g., accounting, banking, finance, management, and business) and the lack of STEM graduates (CDRI, 2015; World Bank, 2012), as well as to encourage higher education institutions to devote more attention to STEM related (e.g., mathematics; the natural sciences, including the physical sciences and biological/agricultural sciences; engineering; engineering technologies; and computer/information sciences), MoEYS has suspended issuing licenses to open new programmes and courses related to the above-mentioned non-STEM disciplines (MoEYS, 2014c; 2016b).

In the other continuum, MoEYS has also encouraged and established more higher education institutions offering programmes in STEM fields. Statistically speaking, as displayed in Table 3.3, according to a JICA report (2016) and MoEYS (2016b), among 118 HEIs, 52 currently provides STEM majors; 16 are national institutions and 36 are private. Of the 16 national HEIs, 11 are located in the capital city of Phnom Penh and 5 are in the provinces, while 24 of the private institutions are in Phnom Penh and 12 are in the provinces. This also underscores the role of both national and private universities in offering STEM fields across the nation. Within these 52 higher education institutions, there are 110 faculties and departments of STEM fields. This provides even more diversity for students wishing to pursue their degrees in STEM fields in higher education. Recently, more higher education institutions specialising in STEM and more STEM majors have been created.

Table 3.3: Number of HEIs offering STEM-related majors in Cambodia

	Capital	Province	Total
National HEIs	11	5	16
Private HEIs	24	12	36
Total	35	17	52

Source: Synthesis of JICA (2016) and MoEYS (2016b)

3.2.2 The employment status of graduates

From a broader perspective, according to the World Bank statistics on Cambodia's employment to population ratio has remained at approximately 81.748 during the latest five years. Specifically, in 2020, the ratio was 81.802 (World Bank, 2020). In the region's higher education landscape, overall, information on graduate employment, labour markets, and skills remains weak since the institutions do not systematically attempt to gather recent graduates' feedback about the workplace relevance of their courses and training programmes, which would allow these institutions to make changes to their curricula and programmes (World Bank, 2012). Recently, a nationwide tracer study was conducted in 2015 to follow up with the total samples of 4,628 graduates from 33 of the 119 HEIs. The study revealed that 78% of them were engaged in paid employment or 89% of graduates were engaged in income generation activities after graduation (MoEYS, 2015). Interestingly, a greater percentage of science and engineering related graduates (versus their non-science and engineering counterparts) tended to earn higher. Although the study by CDRI (2015) showed that science and engineering and non-science and engineering graduates earn nearly the same wages, the tracer study report revealed that a higher proportion of students from science-related institutions earn more money. Moreover, science and engineering graduates have more advantages in the way that they spent shorter (36% shorter) duration of unemployment before finding a matched job compared to the non-science and engineering graduates (Sam, 2018). However, many students are not aware of the huge range of STEM careers that they can choose to enter (MoEYS, 2016b). Only one in five graduating secondary students bases their decision on what to study on the job market (World Bank, 2012).

3.2.3 Brief strategies and initiatives towards STEM uptake in higher education

As mentioned, Cambodia's education system has shifted to the "6-3-3-4" pattern: six years of primary, three years of lower secondary, three years upper secondary, and four years for a bachelor's degree. (see Appendix 6 for details) (MoEYS, 2018a). Higher education studies consist of a four-year graduate degree (bachelor's) and two (master's) and three-year (doctoral) post-graduate degrees. Also, with the current demand for human resource in STEM in higher education, a number of policy initiatives have been launched at upper secondary school to promote students' uptake from upper secondary school to higher education. Several key initiatives (including tracking system, NGS, and others) are being implemented. This sub-section, therefore, delves into such initiatives.

3.2.3.1 Tracking system at Cambodia's upper secondary school

The purpose of tracking is to help students build strong competence in science and mathematics at upper secondary school and to provide clearer pathways for them to choose majors in higher education (MoEYS, 2010). This bifurcation takes place at the end of grade 10^{th} (the first year of upper secondary school) so that all 11^{th} graders are enrolling in either the science or social science track. The key differences between these two tracks lie in the core subjects, the extent of the emphasis place on the curriculum content, the number of teaching hours, and the subjects and the scoring method of the national exit examination. While the former track centres on science subjects (physics, chemistry, biology, earth-environmental science) and mathematics, the latter focuses on Khmer literature, history, geography, and moral civics. For example, in the science track, the learning hours is five sessions/hours per week for mathematics and three hours for each science subjects with the total scores of 125 and 75 for mathematics and each science subject, respectively. By contrast, in the social science track, three and two sessions/hours per week, with the total scores of 75 and 50, are allocated for mathematics and each science subject, respectively (MoEYS, 2010). This scoring method is also applied to the baccalaureate examination. Table 3.4 illustrates the list of subjects that are given different emphasis in the science and social science tracks. While the students from the science track have to take all science subjects, the students from the social science track take only one lucky-draw-selective science subject in the baccalaureate examination. The subject and achievement have significant influence on the oriented subjects to enrol in higher education (MoEYS, 2009; 2020d).

Table 3.4: Comparison of the focus of the science and social science tracks in traditional upper secondary school

Subjects	Science Track			Social Science Track		
	Hour/week	No. Lesson	Max. Score	Hour/week	No. Lesson	Max. Score
Mathematics	5	23	125	3	14	75
Physics	3	16	75	2	15	50
Chemistry	3	16	75	2	11	50
Biology	3	12	75	2	10	50
Earth-environmental science	2	22	50	2	22	50
Khmer Literatures	3	59	75	5	69	125
History	2	15	50	3	24	75
Geography	2	24	50	3	24	75
Moral civics	2	24	50	3	28	75

Source: MoEYS (2010) and (2011)

Moreover, according to announcement #11 of MoEYS (MoEYS, 2018b), since academic year 2014, the students in the two tracks have been required to take different subjects for their baccalaureate examination (see Table 3.6). While the science track took mathematics, and all science subjects (biology, chemistry, and physics), social science track students need to take only mathematics (in a lower level compared to that of the science track) and possibly one lucky-draw-selective science subject. While the lucky-draw-selective social subject for the science track baccalaureate examination has been *history* for five years straight, the lucky-draw-selective science subject for the social science track was *physics* and *biology* in 2014 and 2015, and *earth-environmental science* from 2016 to 2019, respectively. This is a crucial foundation—especially for the students in the science track—for enrolling in STEM majors in higher education. Some studies (e.g., Erdogan & Stuessy, 2015; Sahin, Ekmekci, & Waxman, 2017; Seymour & Hewitt, 1997; Woolnough, 1994a) have asserted that when upper secondary school students in science track take science and mathematics courses, and attain high achievement in these subjects, this is an influential predictor of their pursuit of STEM majors in higher education. In addition, in the Cambodian context, science and mathematics subjects are the primary subjects for the admissions requirements for STEM majors in higher education (MoEYS, 2009).

3.2.3.2 Secondary resource schools, NGS, and E2STEM schools

A number of developments surrounding STEM infrastructure have taken place. First, to enhance the quality of traditional upper secondary school, some schools have been upgraded into *secondary resource schools*, which are leading secondary schools in all aspects of curriculum implementation, learning outcomes, sharing experiences in teaching and management, school development plans and teacher capacity. Most notably, secondary resource schools have the laboratories, libraries, computer labs, and audio-visual rooms (MoEYS, 2018c) to improve the quality of teaching, particularly in science and mathematics subjects. Currently there are 36 secondary resource schools across the country; MoEYS will extend that number to 50 school in the near future (MoEYS, 2020c). Table 3.5 illustrates the distribution of all subjects and study hours in resource secondary schools.

Table 3.5: Distribution of subjects and weekly study hours in resource upper secondary school

No.	Subject	Grade					
		10		11		12	
		Science	Social	Science	Social	Science	Social
1	Mathematics	6	5	6	5	6	5
2	Physics	4	2	4	2	4	2
3	Chemistry	3	2	3	2	3	2
4	Biology	3	2	3	2	3	2
5	Earth-environmental science	2	2	2	2	2	2
6	Khmer literature	5	6	5	6	5	6
7	History	2	3	2	3	2	3
8	Geography	2	3	2	3	2	3
9	Moral civics	2	3	2	3	2	3
10	Foreign language	6	6	6	6	6	6
11	Physical education and sports	2	2	2	2	2	2
12	Home economics	1	1	1	1	1	1
13	ICT	1	1	1	1	1	1
14	Health education	1	1	1	1	1	1
Total weekly hours		**40**	**40**	**40**	**40**	**40**	**40**

Second, in aiming to produce more students with high competency, knowledge, and expertise (to develop both the economy and the overall strength of society), MoEYS recently piloted the so-called *New Generation School* (NGS). The main goal of these schools is to increase educational quality throughout the entire education system, especially science and mathematics-related subjects at upper secondary schools. According to MoEYS (2016b), though it is a pilot school, NGS are aimed to deeply enhance the presence of educational innovation throughout the school system that empower the Cambodia's education system to effectively compete with other education systems, and to produce a workforce with 21st-century skills (MoEYS, 2018d). More specific than traditional upper secondary school, NGS increase skill levels in STEM subjects at upper secondary school through intensive capacity building in educational technology, STEM, and inquiry and problem-based learning methodologies. Currently, there are 11 NGS (four primary and seven secondary schools). Among these seven secondary NGS, three are located in Phnom Penh and four in the provinces (Sam, 2020). Most noteworthy, since NGS is the pilot project, only two secondary NGS are currently accepting and training grade 11th of upper secondary school level students: Sisovath upper secondary school and Hun Sen Kampong Cham upper secondary schools. Other five NGS will train upper secondary level in consecutive academic year.

In 2017 a similar type of school, E2STEM school has been established in Phnom Penh. This type of school is a public-private partnerships between MoEYS, Cambodia, and an international non-profit organisation (NGO) called E2STEM Education. This school aims to bring the best modern practices STEM, English, and e-learning into Cambodia's education system so as to train Cambodian upper secondary school students and produce 1,000 internationally recognised STEM graduates by 2028. Another unique characteristic of this school is that it integrates upper secondary school and technical college. Students can spend three years on their upper secondary education and pursue another two years of technical-skills training. Currently, MoEYS has been equipping the experimental equipment for physics, chemistry, biology, and earth-environmental science in this E2STEM school to promote students' learning.

The main difference between NGS and traditional schools is the number of teaching and learning hours. The teaching hours for mathematics and other science subjects (physics, chemistry, biology, and computer science) have been increased to six and four hours per week, respectively. Table 3.6 exhibits the different numbers of hours by subject that students in traditional and NGS schools need for studying each week, and the subjects they need to focus on for the national examination.

Table 3.6: Teaching hours for the social science track, the science track, and NGS

No.	Subject	Traditional Upper Secondary School		NGS	Subject for Baccalaureate Examination[1]	
		Social Science	Science	Science	Social	Science
1	Mathematics	3	5	6	C	C
2	Physics	2	3	4	L	C
3	Chemistry	2	3	4	L	C
4	Biology	2	3	4	L	C
5	Earth-environmental science	2	2	1	L	L
6	Khmer Literature	5	3	5	C	C
7	History	3	2	2	C	L
8	Geography	3	2	2	C	L
9	Moral civics	3	2	3	C	L
10	Foreign Language	2	2	4	C	C
11	Physical Education	1	1	1	N	N
12	Economic	2	2	1	N	N
13	Technical Education	2	2	4	N	N
Total		**32**	**32**	**40**	**7**	**7**

Overall, the number of teaching hours has risen to 34 hours per week for primary schools and 40 hours per week for secondary schools. This required increase is meant to provide access to special subject themes that focus on STEM subjects, foreign languages, or other areas of interest to the local community. Moreover, since the expanded number of teaching hours is ultimately intended to increase students' enrolment in STEM fields in higher education, students in NGS are streamed to focus on mathematic, physics, chemistry, or biology. Next, as in the policy, the teachers in NGS are supposed to use more interactive teaching methods that help boost students' interest in STEM (MoEYS, 2018e). This ensures that teachers adhere to official guidelines requiring them to teach full-time (18 hours per week for lower secondary school teachers and 16 hours per week for upper secondary school teachers). Last, since students need to take a full-time course load at school, there is no time for them to have private tutoring, which is a common practice for students in the traditional upper secondary schools.

[1] ***C***: Compulsory subject for the baccalaureate examination, ***L***: Lucky-draw selective subject for the baccalaureate examination, ***N***: Not included as a baccalaureate examination subject. One of the four lucky-draw selective subjects will be chosen (at ministrial level) as another compulsory subject for the baccalaureate examination in each study track. A total of 7 subjects will be included on the examination.

3.2.4 Other initiatives to promote STEM aspirations

A number of extracurricular initiatives are being implemented to foster students' aspirations. More practically, MoEYS and the British Embassy in Cambodia recently published the *STEM Career Booklet* listing potential STEM careers and Higher Education Institutions (HEIs) that offer STEM majors in Cambodia to give upper secondary school students the chance of better guidance, and to help them make well-informed choices in matriculating into STEM fields in higher education (British Embassy, 2016).

Also, aiming to increase students' interest in pursuing STEM majors in higher education, other extracurricular activities such as the *STEM Bus* (a mobile vehicle that brings science experiments to secondary students across the country), and the *Science and Engineering Festival* (to raise public awareness of STEM) have been conducted. To date, the bus has travelled to 123 upper secondary schools and 4 lower secondary schools in the 25 provinces of Cambodia, and the 16th annual STEM festival was held in 2020. Some secondary school students have been invited to join the event. MoEYS has also encouraged the formation of mathematics and physics study clubs *(Science Clubs)* at 36 upper secondary schools in Phnom Penh. However, the effects of these programmes on student's aspirations of STEM majors are greatly underrated.

3.2.5 Admission into the higher education system

In terms of the admissions process of Cambodia's higher education, the successful completion of a baccalaureate degree is not the only pathway; it is merely the primary route. Overall, there are two types of admissions: scholarship and fee-paying (MoEYS, 2002). Scholarships, (and government scholarships through MoEYS in particular) are provided based on four main priorities: (1) merit, (2) gender, (3) poverty, and (4) geographical location. To apply for government scholarships, students must choose any two majors (as their first and second priorities) (MoEYS, 2018f) in any HEIs of their interest listed in the MoEYS booklet and apply through the Department of Higher Education (DHE) in the second semester of grade 12th of each respective academic year. The application process starts in mid-March and lasts until the end of May. The selection is mostly grounded in the students' performance on the baccalaureate examination. However, to be enrolled into STEM majors at some prestigious HEIs—such as engineering at the Institute of Technology of Cambodia (ITC) and health science at the University of Health Science (UHS)—students must take the entrance examination. To be accepted into the ITC, students need to take an exam on advanced mathematics, physics, chemistry, and logic examination. To be enrolled into UHS, students need to take an exam on mathematics, chemistry, and biology. Each applicant is eligible to win only one government scholarship at a time (either the first or second priority, depending on their grade obtained on the baccalaureate examination or the entrance examination). Moreover, each applicant can apply for more than two scholarship priorities for which they are eligible (merit, poor, female, and rural).

Table 3.7 presents the number of upper secondary school leavers and the share of scholarship recipients from 2011 to 2020. Although the percentage of government scholarships offered to upper secondary school students comprises a small portion, this figure roses from approximately 6% in academic year 2011–2012 to about 11% in academic year 2014–2015, then fell to about 10% in academic year 2018–2019. As stated in the ESP for 2014–2018 (MoEYS, 2014a), MoEYS aimed to increase the proportion of public student scholarships to 15% by 2018.

Table 3.7. Percentage of scholarship students compared to upper secondary school leavers

Year	Number of scholarship students via MoEYS	Number of Upper Secondary School leavers	% Scholarship/Upper Secondary School leavers
2019-2020	7,597	79,052	9.61
2018-2019	7,444	75,873	9.81
2017-2018	6,734	63,668	10.57
2016-2017	5,026	55,753	9.01
2015-2016	4,380	46,560	9.41
2014-2015	3,589	33,997	10.56
2013-2014	4,116	91,370	4.50
2012-2013	4,450	96,023	4.63
2011-2012	5,638	92,236	6.11

Source: Statistics compiled by Admissions Office, DHE, MoEYS (2020c).

The second type of admission entails fee-paying. Students who passed the baccalaureate examination and do not receive a government scholarship, yet wish to pursue higher education, can be admitted through a fee-paying scheme at either public or private higher education institutions. In academic year 2017–2018, of the 168,242 students with a bachelor's degree, there were 143,605 (about 85%) enrolled under the fee-paying scheme. Most private higher education institutions are providing a similarly narrow range of courses that require little capital investment at the expense of fields that are vital for the country's economic growth (Pit & Ford, 2004).

With either type (scholarship or fee-paying), students are admitted based on two main methods: their scores on grade 12th national examination and the institution's entrance examination. With the first method, if the students passed grade 12th national examination and got a passing grade on the subjects required for enrolling in a certain major, they do not need to take entrance examination. However, they need to take the entrance examination if they pass the grade 12th examination but receive a failing grade for one of the required subjects. For example, if a student passes the grade 12th national exam and gets a passing grade for mathematics and physics, she/he could be enrolled in a mathematics majors in higher education without taking the entrance examination. However, a student needs to take the entrance examination if she/he receives a failing grade in science or mathematics on the grade 12th national examination. Students need to take the entrance examination if they want to be enrolled in a major that requires subjects they did not take on grade 12th national examination. Therefore, science track students have more advantages for being admitted into STEM majors. (See Appendix 8 for a list of some majors and the subjects required.)

3.3 Tracking: Definitions and types

Although the definition of "tracking'" (conventional or selective) is, to some extent shared around the world, countries seemed to differ widely in terms of the type, degree, and age at which students begin to be tracked (Darolia et al., 2018; Dustmann, Puhani, & Schönberg, 2017). Some countries track students into differing-ability schools as early as age 10 (e.g., Austria, Germany, Hungary, and the Slovak Republic). By contrast, others (e.g., Canada, Japan, Norway, Sweden, Korean, the United Kingdom, and the United States) keep their entire lower secondary school system comprehensive (Hanushek & Wößmann, 2006; Organisation for Economic Co-operation and Development [OECD], 2004) and begin tracking students at age 16 years old (Woessmann, 2009). Various scholars have categorized the multiple forms and understandings of tracking into five main types (see Table 3.8 for details).

Table 3.8: Typologies of curricular differentiation across nations

Type 1: *School type*	Differentiation in the organisational forms of schooling (e.g. vocational versus academic high school).
Type 2: *Course of study*	Provision of more than one formal paths that students may follow within a given school or school type (e.g., technical high schools have distinct core classes for their chemistry and electrical engineering course of study.
Type 3: *Stream*	Differentiation occurs over time in terms of the number and difficulty of course assigned to different streams (e.g., liberal art versus science stream in Japanese high school). Other terms include tracking or lanes.
Type 4: *Ability grouping*	Grouping occurs within one class or grade or "pulled out" to study elsewhere, on the basis of some measure or estimation of students' ability (e.g., ability-based reading group, gifted and talented programmes).
Type 5: *Geographical location*	Differentiation in curricular offerings, instructional quality, and opportunity to learn differ by geographic area where schools are located (This is most prominent in the U.S).

Source: Adapted from LeTendre et al. (2003)

Based on the aforementioned definitions and types outlined in Table 3.8, tracking in Cambodia typically falls into types 1 and 3. For type 1, at the end of grade 9th students could choose between a technical/vocational or academic upper secondary general education tracks (see Appendix 6 on education system of Cambodia) (JICA, 2016; UNESCO, 2014). However, this kind is beyond the scope of the current study. For type 3, by the end of grade 10th, students are divided into two main tracks: science and the social science (for their grades 11th and 12th). (The previous section discussed the details.)

3.4 Empirical evidence for students' choice of STEM major: Global perspectives

Flourishing STEM education, especially in higher education, is indispensable to long-term economic growth and stability (Kier et al., 2014; Sahin, Gulacar, & Stuessy, 2015). The issues pertaining to the low uptake in the field should not be overlooked. To address the issues surrounding low participation in STEM fields or the shortage of graduates resulting from the decline in students' interest in (and lower attitudes towards) studying science, effective initiatives and strategies implemented in the other countries merit consideration. To achieve this objective, the researchers desk-reviewed, analyzed, contrasted, and synthesized existing policy documents and literatures on policy initiatives implemented to promote students' understanding and to enhance their matriculation from the science track at upper secondary school into STEM fields in higher education. The researcher compare *STEM: Country comparison report* on Canada, France, Japan, the United Kingdom, and the United States. The key data sources were policy documents and articles, including a 2013 report comparing Canada (Weinrib & Jones, 2013), France (Oliveira & Roberts, 2013), Japan (Ishikawa et al., 2013), the United Kingdom (Tomei et al., 2013), and the US (Maltlese, Lung, Potvin, & Hochbein, 2013), as well as educational policies and practices in STEM and science education in Europe. These include national policies, practices, and research (Freeman et al., 2015). These *STEM country comparison reports* were the synthesis of the extant studies and reports on each respective country.

There were three main justifications for selecting the aforementioned countries for comparison. First, by definition, in *STEM: Country comparison reports*, these nations excluded social and behavioural sciences from the category of "STEM fields" (Chen, 2013; Crisp et al., 2009; Marginson et al., 2013; MoEYS, 2016b; Ulicna & Royale, 2015). This was in congruence with the classification of STEM fields in the Cambodian context. Second, based on the share of tertiary graduates in STEM and the gender distribution from the 2015 Organization for Economic Cooperation and Development [OECD] database (OECD, 2017), France and the United Kingdom (whose shares of tertiary graduates in STEM fields were above the OECD average) and Canada, Japan, and the United States (with the shares below the OECD average) were selected to be the comparator countries. Lastly, all of the chosen countries have experienced and overcome the decline in students' interest in (and negative attitudes towards) science and participation in STEM fields as they transitioned to another stage of industrial development (Marginson et al., 2013).

In addition to reviewing the initiatives to promote STEM uptake, the researcher also conducted a comprehensive review on a large number of empirical studies on factors that explain students' choice of STEM majors in higher education. The literature revealed diverse variables that empirically influence students' choice of STEM majors. The researcher thus synthesized the findings from these empirical studies, along with the policy initiatives.

Conceptualized through the lens of the synthesised theoretical and conceptual models, and given that some attitudinal and belief variables change over time (e.g. Barmby, Kind, & Jone, 2008; George, 2006; Navarro, Flores, & Worthington, 2007; Siegel & Ranney, 2003; Tan & Laswad, 2007; Wang, 2017), the researcher then classified the factors into two sub-components: time-invariant and time-varying predictors. Next the researcher categorized these two components as predictors at the individual level, predictors at the family level, and predictors at the upper secondary school level.

3.4.1 Time-invariant predictors

3.4.1.1 Predictors at the individual level

A large body of literature on students' choice of STEM majors at the individual level perspective was based on theorists' interests. Normally, behaviourists look at the factors that affect students' choice through the lens of students behaviours. Similar practices are applied when the psychologists or experts in academic achievement examine this phenomenon. The first area to investigate regarding the factors involved in the students' science outcomes in choosing a STEM major entailed personal ability and affective factors. In this section, the study discusses on the effects of gender on students' choice to transition from the science track at upper secondary school to a STEM major in higher education.

3.4.1.1.1 Gender

From gender perspective, gender differences in STEM majors participation in higher education are by no means new, and have generated debates among researchers for several decades. A central question was whether these distinctions springed from genetic differences (e.g., in mathematical aptitude between young men and women) or from gender stereotypes. However, evidence indicates that socio-cultural factors and constraints constitute the most powerful explanatory factors underlying women's underrepresentation. For example, Trusty, Robinson, Plata, and Ng (2000) which investigated the effect of gender on post-secondary educational choices, found that men choose STEM majors more frequently than women do. This result is consistent with Eccles's (1994) model of achievement-related choices and the work of Sahin, Ekmekci, and Waxman (2017). Together, they contended that the cause of the difference is that women and men differ in their subject task values. While women placed more importance on language-related skills and tasks, men placed more value on mathematics-related skills and tasks. Eccles (1994) and Riegle-Crumb and King (2010) added that this difference explains the lower frequency of women entering into science and mathematics fields. Moreover, Whitelaw, Milosevic, and Daniels (2000), confirmed that gender is probably the most important variable related to attitudes towards science. To support this, many studies for instance, Francis and Geer (1999), Gunderson, Ramirez, Levine, and Beilock (2012), and Jone, Howe, and Rua (2000) reported that males have more positive attitudes towards science and mathematics than females. Recently, Lavy and Sand (2015) signalled that some teachers have a biased belief of female inferiority in mathematics and tended to give lower score to female students, and this had long-term effects on students' attitudes towards mathematics and STEM majors. Also, males tended to perform better than females in science and mathematics subjects (Hill & Tyson, 2009; Steffens, Jelenec, & Noack, 2010) and more likely to be involved in disciplines that required advanced mathematics and science (Osborne, Simon, & Collins, 2003; Seymour & Hewitt, 1997). In the same vein, men are almost twice as likely as women to cite being good at mathematics and science in high school as a reason for choosing STEM majors in higher education. However, some recent studies (e.g. Dom & Yi, 2018; Lee, Min, & Mamerow, 2015; Nix, Perez-Felkner, & Thomas, 2015; Riegle-Crumb, King, Grodsky, & Muller, 2015) have argued that gender gaps in some STEM majors are not fully explained by achievement in science and mathematics. Rather the gender stereotypes, which are closely related to environmental factors than individual characteristics, that influence the less likelihood of females majoring STEM. In sum, a man is found to be significantly more likely to choose a STEM major than a woman (Crisp, Nora, & Taggart, 2009; Hackett, 1985; Kao & Shimizu, 2019; Kelly, 1988; Montmarquette, Cannings, & Mahseredjian, 2002; Nosek & Smyth, 2011; Porter & Umbach, 2006; Seymour & Hewitt, 1997; Song & Glick, 2004; Vooren, Haelermans, Groot, & Van den Brink, 2019; Wang, 1995; Westrick, Radunzel, & Bassiri, 2018). To date, the conclusion on whether this difference stems from performance or behavioral differences remains a controversial idea.

3.4.1.2 Predictors at the family level

Interests of the social science researchers often have their explanations for different outcomes in science (students majoring in STEM) emphasize on the deficiencies within students' homes. According to human capital theory, the home is an area where students gain differential exposure to cultural capital from their families, and different access to networks within their communities. Researches have also revealed several home environmental variables that could influence students' choice of STEM majors in higher education including parental factors, socio-economic factors, and relatives' influence.

3.4.1.2.1 Parental education

In terms of family educational background, parents' education level has a significant effect on children's choice of major (Shim & Paik, 2014; Wei et al., 2014). A higher percentage of the students majoring in STEM have at least one parents who also studied STEM in higher education (Moakler & Kim, 2014; Sonnert, 2009; Ware, Steckler, & Leserman, 1985; Woolnough, 1994a, 1994b). This finding was confirmed by Fleming, Engerman, and Griffin (2005), who investigated students at historically black colleges and universities that pursued a STEM major; they found that students were impacted in their choice to major in STEM due to their parents' education level. Similarly, children of less educated parents are markedly less likely to enrol in post-secondary education of any kind, which is an automatic disqualification from STEMM (Miller & Kimmel, 2012). Highly educated parents are more likely to encourage their children to learn about science overtly and indirectly through science-related books, materials, and toys. If their parents (especially the mother) have a high level of education, students' probability of choosing science and engineering is also high. However, for male scientists, an increase in parental education level is associated with a steeper increase in the likelihood of the parents named as the influencer, whereas this increase was lower for female scientists. This finding is consistent with the finding that women are more likely to choose male-dominated majors and careers in science and engineering if their father has a high level of education. In this respect, women with highly educated fathers are more likely to major in science and engineering than those who do not (Lapel, Williams, & Waldauer, 2001; Miller & Kimmel, 2012). In short, the increase in parents' educational level (and especially parents who majored in STEM) increases the probability of the students to major in STEM in higher education. The highest parental degree was found to influence one's choice of STEM majors (Wang, 2013; Sax, Kanny, Riggers, Whang, & Paulson, 2015; Ruse & Xu, 2018). This effect is even stronger for females with parents having higher degrees (Leppel, Williams, & Waldauer, 2001; Sahin et al., 2017). Parental education also has a significant effect on students' attitudes towards science, which in turn influences their choice of STEM majors (Hacieminoglu, 2016). Moreover, decades ago, a study employing the dichotomous dependent variable of science and non-science also found that having highly educated parents increased the probability of women choosing to major in science, but this outcome is negatively for boys (Ware et al., 1985).

3.4.1.2.2 Parental occupation

Besides parents' education, the significant influence of parents' occupation on one's choice of major has also attracted attention from social researchers. Today, parental factors that influence an individual's choice of major extend beyond parents' level of education, to their occupations. Parents certainly make a difference in their children's interests and choices. In particular, parents would exert a major influence on their children's interest in science, choice of major in, and career in science (Bleeker & Jacobs, 2004; Dick & Rallis, 1991; Harwell, 2012; Kao & Shimizu, 2019; Seymore & Hewitt, 1997). Parents who work in Science, Technology, Engineering, and Mathematics (STEM) fields have a positive impact on their children choosing to major in STEM. To reiterate, if students' parents work in a STEM career, their likelihood of pursuing a STEM major also increase, thus following family tradition (Crisp & Nora, 2006; Eng & Szmodis, 2016; Harwell, 2012; Kao & Shimizu, 2019; Leslie, McClure, & Oaxaca, 1998; Seymore & Hewitt, 1997; Woolnough et al., 1997). Students, from their efficacy beliefs, see such a major and career as feasible. Most noteworthy, Sonnert (2009) found that the closer the parents' job are to science-related professions, the more likely they are to influence their children's choice of a science major. Thus, empirically speaking, parents' occupation has a significant effect on students' choice of major in higher education. The probability of students choosing a STEM major increases if their parents work in a STEM fields; this effect is stronger if the father works in a STEM area (Leppel et al., 2001).

3.4.1.3 Predictors at the school level

In the previous section, the researcher outlined how family background predictors can influence the students' choice of STEM majors. These factors are important, but school practices are also crucial for understanding the landscape of students' choices. In particular, upper secondary schools provide a pivotal time for students to decide whether to pursue a STEM-related major and career (e.g., Darolia et al., 2018; Lee, Min, & Mamerow, 2015; Maltese & Tai, 2011; Shimpkins et al., 2015). Upper secondary schools can either encourage students to learn science and mathematics to gain literacy and thus choose to enter the STEM pipeline, or they can push students away from the pipeline. The section that follows, thus, discusses how each aspect of upper secondary school predictors impacts students' STEM majors in higher education.

3.4.1.3.1 Tracking/Streaming system

For decades, researchers have sought to understand the effect of tracking/streaming (in science) on one's choice of major in general, and for STEM majors in particular. Zuniga, Olson, and Winter (2005) examined the tracking policy of high schools among Hispanics and found that this policy might negatively influence students' academic experiences in mathematics and science. Consequently, students who were placed in a lower-level science track, regardless of academic ability, are unlikely to take subsequent courses required for college admissions despite that most of them have college aspirations; they are thus turned off by science in higher education. In contrast, students in the science track at upper secondary school are more likely to pursue their education in science-related majors (Kao & Shimizu, 2019; Kinyota, 2013; Lee, 1987; Li & Kuan, 2018; Myeong & Crawley, 1993; Paik & Shim, 2013; Shim & Paik, 2014; Trusty, 2002; Wang & Lee, 2019). Studies have confirmed that students in the science track are more able to experience and be involved in (or exposed to) more science and mathematics courses at upper secondary school, and hence have a higher interest in (and attitudes towards) science-related courses. As such, they are more likely to major in science or STEM related in higher education. Moreover, the number of mathematics courses taken has the strongest effect on one's choice of science and mathematics-related majors among women, whereas for men, the number of science courses taken has the strongest effect. On the contrary, students placed in a lower-level humanities/social science track at upper secondary school are more likely to pursue majors with non-intensive science and mathematics.

However, some studies counter argued that merely increasing the number of science and mathematics courses taken in high school does not have any significant influence on the students' choice of STEM majors (Darolia, Koedel, Main, Ndashimye, & Yan, 2018; Maltese & Tai, 2011; Means et al., 2018). Rather, the students' interest in STEM majors is influenced by how science and mathematics courses are actually conducted in the classroom, and the quality of exposure to lessons. In the Cambodian context, aiming to guide students toward higher education in general and science-related in particular, MoEYS has also been implementing a tracking/streaming policy. Students are required to choose either the social science or science track starting in grade 11th (MoYES, 2010). On top of this, NGS have been piloted to promote STEM education and choosing a STEM major. As a result, this study posits that students in the science track or those who attend NGS will be more likely to pursue STEM majors than those in the social science track.

3.4.2 Time-varying predictors

Researchers (e.g. Barmby, Kind, & Jone, 2008; George, 2006; Gibson & Chase, 2002; Navarro, Flores, & Worthington, 2007; Siegel & Ranney, 2003; Tan & Laswad, 2007; Wang, 1995) have demonstrated that some attitudinal and perceptual variables change over time. Therefore, this section addresses the three dimensions variables that were hypothesized to change overtime. The key objective was to investigate if the teaching and learning process in the science and social science tracks at upper secondary school truly has an influence on these variables, and to identify if the multi-dimensional variables influence students' aspirations of STEM majors in higher education.

3.4.2.1 Predictors at the individual level

3.4.2.1.1 Science and mathematics academic achievement

From academic achievement perspective, science and mathematics achievement and choice of STEM major have also gained attention in many scholarly works. Upper secondary school education in science and mathematics is an essential starting point for building a logical extension into STEM majors in higher education. In this regard, science and mathematics achievement from upper secondary school is often an influential factors in students' choice of STEM major. Empirically, strong pre-college academic achievement in science and mathematics positively affects students' decision to pursue a STEM major (Almeida, Leite, & Woolnough, 1998; Bonous, 2000; Kao & Shimizu, 2019; Kelly, 1988; Lent, Lopez, & Bieschke, 1993; Mau & Li, 2018; Miller & Kimmel, 2012; Nicholls et al., 2007; Rask, 2010; Sax, 1996; Selema, 2010; Seymore & Hewitt, 1997; Trusty, 2002; Wang, 1995; Westrick et al., 2018). Students with better performance in science and mathematics during high school are more likely to be self-motivated to declare a mathematic-intensive STEM major due to the fact that these fields require advanced mathematics. In accordance with this finding, Woolnough (1994a), who conducted a study in England and measured the General Certificate of Secondary Education (GCSE) score, found that students with higher or better achievement in science and mathematics courses are more able than non-science majors to be involved in STEM majors. Other studies (e.g., Adelman, 1999; Chen & Weko, 2009; Crisp, Nora, et al., 2009; Lent, et al., 1993; Nicholls, et al., 2007; Wang, 2013; Woolnough, 1994b; Woolnough et al., 1997) have also confirmed this finding. Porter and Umbach (2006) discovered no significance of science and mathematics achievement in one's choice of STEM majors in higher education. Most empirical evidence has revealed that this choice is significantly influenced by science and mathematics achievement in high school.

3.4.2.1.2 Science and mathematics self-efficacy

From a psychological perspective, besides science and mathematics academic achievement, science and mathematics self-efficacy also have a considerable influence on choosing science and engineering-related majors. Findings from many studies have indicated that science and mathematics self-efficacy beliefs are positively linked to college students' choice of science and mathematics related academic majors (e.g. Lent et al., 2018; Sahin et al., 2017; Wang, 2013; Wang & Lee, 2019). Crucially, despite moderate science and mathematics achievement, students are more likely to sign up for STEM majors if they have high levels of science and mathematics self-efficacy; that is, the belief in one's ability to successfully perform in that academic area (Bandura, 1986; Bethz & Hackett, 1983; Crisp & Nora, 2006; Meece, Parsons, Kaczala, Goff, & Futterman, 1982; Seymour & Hewitt, 1997). Moreover, Leslie, McClure, and Oaxaca (1998) also confirmed that the probability of choosing a STEM major increases with students' perceptions that they possessed a solid science and mathematics background, and in the belief that they can perform well in those courses. In a sense, science and mathematics self-efficacy is influenced by one's mathematics and science background, which in turn affects technical and scientific interests or academic choice of majors (Hackett, 1985; Lent et al., 2008; Lent, Lopez, & Bieschke, 1993; Nugent et al., 2015; Scott & Mallinckrodt, 2005; Turner, Steward, & Lapan, 2004; Wang, 2013). For example, DeBoer (1987) indicated that students with high confidence in their ability, and who expect to do well in scientific fields, are more likely to take more STEM majors (Nauta & Epperson, 2003). Strongly self-efficacy tends to influence their academic achievement, and in turn students' choice of STEM majors.

From a gender perspective, there are significant gender differences in terms of science and mathematics self-efficacy. According to (Betz & Hackett, 1983; Eccles, 1994; Lapan, Boggs, & Morrill, 1989; Lent, Lopez, & Bieschke, 1991; Matsui, Matsui & Ohnishi, 1990; Seymour & Hewitt, 1997; Strayhorn, 2015; Wang, 2013), males have stronger science and mathematics efficacy than females. However, recent research suggests that this gender gap may be closing. The study revealed that there was no gender difference in terms of how science and mathematics self-efficacy works to influence students' choice of major in a STEM-related field (Wang, 2013). Notwithstanding, interestingly, a recent study conducted by Lowinger and Song (2017) found that mathematics self-efficacy does not predict one's choice of STEM major, as those who reported higher mathematics self-efficacy tended to major in business rather than STEM. Further, it was explained that Asian American students who are proficient in mathematics tend to be more modest regarding their mathematics ability (Lee, 2009; Lowinger & Song, 2017).

3.4.2.1.3 Attitudes towards science

For decades, a problem that has been raised when studying about attitudes towards science is the definition of attitude itself (Francis & Greer, 1999; Germann, 1988; Osborne, Simon, & Collins, 2003). The controversy stems from the fact that there are many concepts that related to attitudes towards science that might not be included in each definition. However, the most common definition involved in describing attitudes encompasses the three components of cognition, affect, and behaviour. As such, attitudes towards science in this study, according to (Bagozzi & Burnkrant, 1979; Gardner, 1975; Kind, et al., 2007; McGuire, 1985; OECD, 2016; Yara, 2009), entail feelings, beliefs, and values held about science (that may be a school of science), the impacts of science on society, or careers in science.

Concerns about attitudes towards science and choice of STEM majors are not new. From a behaviourist standpoint, nearly 30 years ago, Ormerod and Duckworth (1975) had begun their review and emphasized that among the factors that had been lessening or swinging students away from science was due to the lessening of their attitudes towards science. In addition, more studies on attitudes towards science have confirmed that such attitudes not only consist of a single unitary construct, but rather a large number of sub-constructs, all of which contribute in one's attitudes towards STEM (Osborne, Simon, & Collins, 2003; Ventura, 1992). To support this, studies by (e.g., Breakwell & Beardsell 1992; Brown, 1976; Conrad, Canetto, MacPhee, & Farro, 2009; Crawley & Black 1992; Gardner, 1975; Haladyna, Olsen, & Shaughnessy, 1982; Kao & Shimizu, 2019; Koballa Jr., 1995; Osborne, Simon & Collins, 2003; Nicholls et al., 2007; Woolnough, 1994a) which incorporated a range of components into their measures of attitudes towards science including perception of science teachers, anxiety about science, the importance of science, self-esteem in science, the motivation towards science, enjoyment of science and the nature of science classroom environment and so on, found that students with a low self-rating on attitudes measures are less likely to be engaged in STEM majors. In line with this, Menis (1989) argued that the assessment of student's attitudes towards science should be concerned with at least three distinct referents: (1) attitudes towards the importance of science, (2) attitudes towards science as a career, and (3) attitudes towards science in the school curriculum. He further indicated that when these three distinct referents are positive, students also have more positive attitudes towards science.

As consequent, in 2007, Kind, Jones, and Barmby, developed and validated another attitudes towards science measure that covers seven sub-constructs: (1) learning science in school, (2) self-concept in science, (3) practical work in science, (4) science outside of school, (5) future participation in science, (6) the importance of science, and (7) general attitudes towards school science. They discovered that students are more likely to make choices that will lead to science-related majors. In gender debate perspective, male students have more positive attitudes towards science than female students (Crisp & Nora, 2006; Francis & Greer, 1999; Hodson & Freeman, 1983; Simpson & Oliver, 1990; Weinburgh, 1995). From time perspective, it was found that students' attitudes towards science declined as they progress through secondary school, and the decline is more pronounced for females (Barmby et al., 2008; Gibson & Chase, 2002; George, 2006; OECD, 2016; Osborne et al, 2003; Zhou et al., 2019).

Although there have been diversed measures, attitudes towards science itself are strongly determined differently by three independent constructs: (1) self-related variables, (2) teachers, and (3) the learning environment (Freedman, 1997; Papanastasiou & Papanastasiou, 2004; Zacharia & Barton, 2003). Consequently, there has been some agreements on attitudes referenced to personal characteristics. From a gender perspective, male students have higher positive attitudes towards science than female students (Crisp & Nora, 2006; Francis & Greer, 1999; George, 2000; Hodson & Freeman 1983; Kao, 2019a; OECD, 2016; Simpson & Oliver, 1990). In a sense, males exhibits significantly higher positive attitudes towards science than females. Studies reported that, over time, female tended to have lower ratings of attitudes towards science, which are likely related to their self-concept and their notions of male dominance in science classes and careers (Handley & Morse, 1986; OECD, 2016). However, this is not always the case for all science subjects. Weinburgh (1995) revealed that boys usually show more positive attitudes towards physics and chemistry because they are much more interested in speed, electrical circuits, and technological applications in physics.

Regarding the teaching and learning environment, findings from previous studies also showed that students' attitudes towards science generally declined over the period of middle school and high school years (Barmby et al., 2008; George, 2006; OECD, 2016; Osborne et al., 2003 Simpson & Oliver, 1990). Research also consistently indicates that, since the attitudes scale is linked to the numbers of science classes taken, it is possible that the decline in students' attitudes towards science could be related to the different types and levels of science courses they take at school. Hence, tracking systems have a significant impact on students' attitudes towards science. Students in the science track are able to experience and be more involve in science and mathematics courses, which consequently leads to higher positive attitudes towards science-related courses in the future (Kao, 2019a; Marginson, et al., 2013; Myeong, et al., 1991).

From the angle of locality, in the discourse on nationality, studies showed that attitudes towards science are not the same (Awan et al., 2011; Barmby et al., 2008). The attitude in general and attitudes towards science in particular varied remarkably in different parts of the world, and students' nationality affects this variation (Ye, Wells, Talkmitt, & Ren, 1998). Surprisingly, compared to developed countries, children in developing nations appear more interested in science and science-related topics. In a narrower geographical area perspective, results also showed two contrasting schools of debate. Measuring the same constructs of attitudes towards science using test of science related attitude (TOSRA), Anwer, et al. (2012), George (2000), Kao (2019a), Papanastasiou and Papanastasiou (2004), and Serin and Mohammadzadeh (2008) consistently verified the stance that students from non-urban areas seem to rate higher on science attitudes scales compared to students from urban areas. However, some other studies (see, for example, Hammrich, 1998; Zacharia & Barton, 2004), maintained that due to environmental advantage, students from urban origins usually have higher positive attitudes towards science than students from non-urban localities. These debates have laid bare the gaps for future research to fill, especially in the developing state like Cambodia. Studies that investigate the effects of attitudes towards science on one's choice of majors in science-related are crucial.

3.4.2.1.4 Outcome expectations

Outcome expectations, one of the key constructs in social cognitive career theory (SCCT), involve the imagined consequences of performing a particular behaviour (If I do this, what will happen?) Similarly, in thought, the types of outcomes people anticipated depend largely on their judgements of how well they will be able to perform in given situations (Bandura, 1986; Betz & Hackett, 1983; Hackett & Bethz, 1981; Lent et al., 2018; Nugent et al., 2015). SCCT posits that outcome expectations were critical mediators of academic interests development. Thus, outcome expectations have become one of the key focus in the academic studies on predicting one's choice of major. Empirically, a number of studies (e.g. Fouad & Smith, 1996; Nauta & Epperson, 2003; Nugent et al., 2015; Wang, 2017) have confirmed that outcome expectations positively influence students' choice of STEM majors. It was claimed that when testing STEM intention as a proxy, outcome expectations have the biggest positive effect of all on the students' choice of majors. This result implies that an individual's intention to engage in a certain activity helps to organize, guide, and sustain individual's efforts over a period of time (Fouad & Smith, 1996; Nugent et al., 2015; Wang, 2013, Wang & Lee, 2019). The combination of ability, learning experiences, and self-efficacy lead to more positive outcome expectations (Nauta & Epperson, 2003). Most noteworthy, it was found that there is a relationship between gender and outcome expectations. Using paths analysis, Fouad and Smith (1996) revealed that male students have higher outcome expectations than female students. Moreover, it was exhibited that students develop higher outcome expectations when parents stress the importance and the value of majors, and support STEM experiences and efforts not only inside, but also outside of school (Nugent et al., 2015).

3.4.2.1.5 Hours spent self-studying

Time spent outside of school has been reported to have a positive effect on students' interest in STEM majors. The variation of this effect might depend on the moderators such as programme focus, grade level, and the quality of the programmes. Prior researches has recognized the effect of out of school time (OST) as a positive, contributing factor to academic success of students in mathematics. Further, the study also provided an assessment of the extended benefit of OST programme on student interest in STEM. With that said, STEM programmes that are exclusively academic are less effective in promoting students' interest in STEM. As it was indicated, students' interest is not sufficiently developed in OST settings that lack a social focus. Moreover, the adolescent years are crucial for fostering and maintaining interest in STEM. Lastly, the synthesis suggested that well-designed studies are more effective at promoting interest in OST STEM programmes (Young, Ortiz, & Young, 2017).

On the other continuum, OST includes the hours spent self-studying or doing homework. It was claimed that as the number of hours spent self-studying or doing homework per week increases, the likelihood of choosing a STEM major increases. It was found that the effect is more visible the more hours a student spends self-studying. For instance, students who study or do homework 20 hours or more each week, are approximately 1.6 times more likely to choose a STEM major (Moakler & Kim, 2014; Trusty, 2002). From a gender perspective, Trusty (2002) indicated that time spent on homework is weakly and positively related to male students' choice of science and mathematics-related majors in comparison to female students. For women, the amount of time spent on homework outside school only has an indirect effect through course-taking. In this regard, due to the limited empirical evidence and the contextual gap in Cambodia, the current study aimed to investigate whether the amount of time the students spend self-studying or doing homework at home is significantly associated with aspirations of STEM majors in higher education. This effect is predicted to enhance students' academic achievement, especially in science and mathematics.

3.4.2.2 Predictors at the family level

3.4.2.2.1 Family income

Since choice of academic major does not only reflect one's social, cultural, and economic background, but also determines one's future educational, social, and economic development, it could help to either maintain the status quo or to break it depending on the pattern of how students self-select into different study fields and career paths (Brand & Xie, 2010; Goyette & Mullen, 2006; Niu, 2017; Seymour & Hewitt, 1997; Xie, Fang, & Shauman, 2015). An investigation of STEM enrolment, from the socio-economic perspective, suffered from both low quantity and inconsistent findings, particularly on the direction of the association between family SES and patterns of choosing one's major (Nui, 2017).

Notwithstanding, there seem to be two schools of debates. Some studies have found that students with high SES are more likely to enrol in science majors, while others have concluded that students with high SES are more likely to choose culturally intensive majors, such as social and the humanities (Ma, 2009). For decades, research has suggested that there are fewer underrepresented students with low SES in STEM fields compared to their more socio-economically advantaged counterparts (e.g. Kienzl & Trent, 2009; Mau & Li, 2018; Sianou-Kyrgioy, 2010). Moreover, they even tended to give up on their major after sometimes due to the conflict between the financial burden they carry and the demanding workload of STEM majors (Seymour & Hewitt, 1997; Shaw & Barbuti, 2010). Low SES students receive less assistance with school-related tasks due to their parents' limited education, time, and financial resources, and also have limited access to role models with a college degree (Engle & Tinto, 2008; Kao, 2019b; Kao & Shimizu, 2019). Furthermore, social connections and cultural resources are often scarce. Thus, children from these families may lack educational support from family and school in preparing for college. Nui (2017) and Kao and Shimizu (2019) recently confirmed that family SES is a source of inequality in STEM enrolment, even after controlling for the level of academic preparation. Students with high SES benefit from pushing effects to pursue STEM studies, while low SES students are disadvantaged in making well-informed decisions regarding STEM enrollment. High SES families can provide their children with encouragement, support, and exposure to science, as well as access to any STEM enrichment experiences necessary to develop and sustain early interest, confidence, and aspirations in STEM fields (Xie, Fang, & Shauman, 2015). In addition to the home environment, the context of high school and the mathematics/science curriculum offered to students varies greatly, with schools serving low SES families providing few STEM educational opportunities to students (Becker, 1986; Conrad, Canetto, MacPhee, & Farro, 2009; Oakes, 1990).

On the other continuum, others counter argued that for economically disadvantaged students, the decision to attend college and arguably major in STEM is rooted in cultural norms and expectations. They found that economically disadvantaged students generally have more confidence in their STEM majors than their high-income counterparts (Brand & Xie, 2010; Lichtenberger & George-Jackson, 2013). Socio-economic status continues to exert significant influence well beyond general education level, since high SES students make up a disproportionate percentage of those obtaining STEM degrees (Chen, 2009; Ware & Lee, 1988). Though family background plays an influential role in acquiring the academic skills necessary to attain a postsecondary degree, it does not play a direct role in the pursuit and attainment of a STEM degree specifically (Chen & Soldner, 2014; Ma, 2009). Traditionally underserved students with a higher likelihood of being economically disadvantaged have maintained a relatively high level of interest in STEM while traditionally served and well-represented students have maintained a relatively low interest in STEM. Students from high and middle-high income families have significantly lower odds of developing an early interest in STEM relative to their low-income counterparts (Leppel, Williams & Waldauer, 2001; Lichtenberger & George-Jackson, 2013). Also, high school students from low SES families may be more likely to perceive STEM majors as leading them directly to the workforce, potentially reducing the opportunity costs associated with attending college.

3.4.2.2.2 Parental educational aspiration

It has been previously found that family environment plays an important role in students' decision to continue in science (Dick & Rallis, 1991; Grandy, 1992; Huang, Taddese, & Walter, 2000; Miller & Kimmel, 2012; Wells & Gaus, 1991, as cited in Wang, 1995). In questioning way, male students regarded their family environment to be more of an encouraging factor than did female students (Wang, 1995). Furthermore, as to confirm this finding, a study conducted in Korea by Myeong, Jeon, Crawley, and Frank (1991) has also found that parents' intention is an influential factor, and is likely to be stronger for students in the science track than for their counterparts in non-science track. Simply put, the finding claimed that if parents' intention is for their children to study a non-science subject, they may not force their children to comply with their wishes. In contrast, if parents favour science, they will be more determined for their children choose science. In line with this, other research has found that parents' interest in science is greater than in arts, and fathers influence their sons more through their interests, this outcome was smaller for a group of women with professional mothers (Crisp, Nora, & Taggart, 2009; Hodson & Freeman, 1983; Seymour & Hewitt, 1997). Furthermore, the study also discovered that women are about twice as likely as men to choose to major in science and engineering because of the active influence of someone close to them, especially their parents (Seymour & Hewitt, 1997). Cambodian families are no exception. As revealed by a very recent survey conducted by Cambodian Federation of

Employers and Business Associations (CAMFEBA), 10% of the upper secondary school students would follow their parents' intentions, regardless of their own interests (CAMFEBA, 2008). However, the question on how this intention differs between science and non-science track students remains to be investigated.

3.4.2.2.3 Parental encouragement and support

In the family environment, family encouragement and support were reported to be one of the influential factors in students' choice of major. In Asian cultures, children tended to obey their parents and meet parental expectations. Thus, students with greater parental supports are more likely to choose STEM rather than social science or humanity majors (Dom & Yi, 2018; Lent et al., 2018; Shen, 2015; Lowinger & Song, 2017; Miller & Kimmel, 2012). Empirically, students, in an unquestioning way, follow in their family's footsteps so as to support for the family career trend (CAMFEBA, 2008; Malecki & Demaray, 2002; Porter & Umbach, 2006; Seymour & Hewitt, 1997; Simpson, 2001). Thus, students whose family career trend is in science would be more likely to maintain it, although without the impact of parental intention. For example, a study to investigate the factors both within school and outside of school that affect students towards or away from higher education course in one of physical science or engineering in Portugal found that students who majored in this field have more probability of coming from a scientific home background. This reflects the fact that, despite there being no intentional advice from a parent or sibling, student's probability of entering into STEM majors stems mainly from the family member who is working in that field. It was contextually found that parents play an important role in assisting students to select the right academic majors (Durdyev & Ihtiyar, 2019) and in inspiring students' interest in STEM majors and that parental support seems to have a greater influence on STEM interests compared to non-STEM fields (Eng & Szmodiz, 2016). More specifically, based on gender stratification, research has found that there is a disparity across genders. It was argued that parental expectations convey to children could influence females' attitudes towards mathematics and science, and their perception of mathematics and science-related majors (Gunderson et al., 2012; Tenenbaum & Leaper, 2003). In addition, students develop higher self-efficacy and STEM outcome expectations when parents stressed the importance and value of these subjects and support STEM experiences and efforts, both inside and outside school. Perceived parental support also predicts science and mathematics self-efficacy (Lent et al., 2018; Navarro et al., 2007; Nugent et al., 2015; Ekmekci et al., 2019).

3.4.2.2.4 Siblings and relatives' majors

From the perspective of family environment, besides parents, siblings and other close relatives can also play a significant role in students' choice of major. Students' decision of the major is also affected by the experienced family members—siblings and relatives (CAMFEBA, 2008; Kao & Shimizu, 2019; Poeu, 2017; Seymour & Hewitt, 1997). There is a limited number of available empirical evidence to explain this phenomenon. Yet, the study in Cambodia conducted by CAMFEBA (2008) revealed that experienced family members and relatives could orientate students on the majors they should take in higher education. However, the question on how these experienced family members influenced students' choice of science and engineering-related remains to be unanswered. This finding was later confirmed by a recent study by Kao and Shimizu (2019). Study by Seymour and Hewitt (1997) also indicated that in either a questioning way or unquestioning way, students opt for a major based on what their experienced family members are doing; they aimed not only to keep track of the family career trends, but also to obtain a clear vision that the major was feasible for them (Seymour & Hewitt, 1997). The study, thus, seemed to indicate that older siblings or close relatives who majored (or are majoring) in STEM will be a more encouraging factor for students to follow in their footsteps. A recent study has also revealed that young people placed their trust in their family or khsae (meaning "string" or "social network" in Khmer language) in deciding what major to study. One might choose to study a certain degree because in the khsae, older relatives could potentially influence the workplace (Poeu, 2017). In this respect, if family members or close relatives majored (or are majoring) in STEM, this would increase the probability of students pursuing the same field in higher education.

3.4.2.3 Predictors at the school level

3.4.2.3.1 Science and mathematics teachers' support

From the standpoint of social support, science and mathematics teachers in any part of the world can learn an important lesson about attracting students to science-related courses. Upper secondary school science and mathematics teachers have significant influence on students' choice of STEM major. The influences of upper secondary school science and mathematics teachers are critical in inspiring some students to follow them into mathematics or science. Psychologically, students might view them as role models (George, 2012; Kao &

Shimizu, 2019; Malecki & Demaray, 2002; Myeong et, al., 1991; Seymour & Hewitt, 1997; Woolnough, 1991). It was also confirmed that good science and mathematics teachers inspire students to take up majors or a career in these subjects. They are likely to have a positive effects in persuading students to continue with science.

Science and mathematics teachers can interpret the curriculum and interact with students on a daily basis by helping students realize the significance of the subject matter and activities; from their evaluations, teachers can influence how students think about their self-efficacy in the subjects involve, as well as changing students' beliefs about the consequences of choosing science (Gaskell, Mclaren, Oberg, & Eyre, 1993; Lindner et al., 2004; Myeong et al., 1991; Woolnough, 1994a). Seymour and Hewitt (1997) and Mau and Li (2018) also supported this finding, and affirmed that science and mathematics teachers influence students in several ways.

First, good teachers are critical to the development of a strong interest in science and mathematics and to build a good foundation for basic knowledge and skills. The teachers who dazzle, excited, and promote their discipline have often been cited as students' primary inspiration for choosing a science and engineering related majors. The influence of some teachers is vital in inspiring students to follow them into teaching science or mathematics. Therefore, upper secondary school science and mathematics teachers are influential factors in explaining students' probability of choosing science and engineering majors in higher education. Moreover, it was found that teacher's expectations have a long-lasting effect on achievement compared to parents' expectations. It has also been shown that expectations and encouragement from mathematics and science teachers each has strong and positive correlation with students' academic success and pursuit of STEM majors. Research has shown that the crucial role of science and mathematics teachers is increasing students' interest and motivation to pursue STEM in higher education (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Heaverlo, 2011; Lee, Min, & Mamerow, 2015; Palmer, Maramba, & Dancy, 2011; Shumow & Schmidt, 2013). Good high school science and mathematics teachers with genuine personal interest in the subjects they teach are pivotal in inspiring students to follow them into teaching mathematics and science (Seymour & Hewitt, 1997).

From the perspective teachers' gender, female science and mathematics teachers can influence female students in two ways: as passive and active representatives. In the first instance, the sizeable number of science and mathematics teachers may interrupt the cognitive association (i.e. gender schema) that increases girls enrolment in STEM fields. On the active side, female teachers in science and mathematics have been shown to have higher subjective evaluations of their female students and encourage them more than male teachers do (Ma, 2011; Stearns et al., 2016). This is consistent with the ecology model by Erdogan and Stuessy (2015) and Mitchell (2016), who claimed that teachers serve to support students' development, which in turn spiritually supports students to choose a STEM major in higher education.

3.4.2.3.2 Interactive science and mathematics lessons

Along with the curriculum, from a pedagogical perspective, a major part of classroom learning is how teachers educate students and how this influences students' choice of major. Besides quantitative exposure to science and mathematics, the quality instruction also matters in terms of increasing students' interest in STEM majors. Students come to class with unique ways of processing information, and when their teachers' instructional methods match with students' learning styles, they often experienced higher achievement (Rakow & Bermudez, 1993). Science is characterised as a field—independent course where students are expected to ask questions, carry out investigations, look for answers, and come up with formulas (Lee & Luykx, 2006). Moreover, there were also indications that the chosen pedagogy can have an important impact on students' interest. Therefore, teachers should vary their teaching methods and pedagogical novelty (Holmegaard et al., 2014; Potvin et al., 2018) to ignite students' interest in STEM.

A large body of the literature presents convincing conclusions that engaging students in active learning—as well as pedagogical approaches that engage them intellectually and entail thinking, problem-solving, questioning, or analyzing information—can improve their performance and lead them to pursue their intentions in majoring STEM (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Lopatto, 2007; Wang & Lee, 2019). A study on increasing the persistence of college students in STEM majors indicated that active learning experiences are inspiring, as they incorporated classroom teaching practices that engaged students in the learning process; further "active" or "interactive" or student-centered pedagogies (such as collaborative learning) has been shown to increase students' enrolment into STEM majors (Erdogan & Stuessy, 2015; Gibson & Chase, 2002; Graham et al., 2013; Simon, Aulls, Dedic, Hubbard, & Hall, 2015). Therefore, the current study hypothesized that besides the different numbers of courses taken in science and mathematics (science versus the social science track and NGS), interactive science and mathematics teaching at the upper secondary school level would significantly affect students' aspirations of STEM majors in higher education.

3.5 Studies on the choice of STEM major: Cambodian perspective

The mismatch between students' choice of major and the demand for STEM graduates is a long-standing issue. To address the mismatch, it is indispensable to investigate the factors that influence students' choice of STEM majors. However, in the Cambodian context, little research has investigated and provided evidence-based approaches to deal with this problem. Empirically, several studies have conducted to explore the factors influencing Cambodian students' choice of STEM major in higher education. Table 3.9 summarizes their findings. Overall, they are mainly retrospective, cross-sectional studies that only investigated students who had already made a final choice and enrolled in a higher education institution. First, for instance, the study by Kao and Shimizu (2019) retrospectively identified the factors that influenced students' current majors in higher education. The study was conducted with freshmen who had already chosen their academic majors at different higher education institutions to discern the different characteristics among students who had chosen science and engineering (versus non-science and engineering) majors. Moreover, merely extended the scope of the sample from the previous study, another retrospective, quantitative investigation by Eam et al. (2019) also employed the cross-sectional designs to identify the variables that explain Cambodian freshmen's choice of STEM versus non-STEM majors in higher education. Third, although study by Pen (2011) investigated the upper secondary school students' aspirations of the choice of major, the study was a purely cross-sectional, and the samples were limited to 175 students. On top of this, Pen did not focus primarily on the choice of STEM majors, but rather on the choice of academic major in general. In short, due to the conceptual limitations in the extant research in the context, the current study fills the gap in the literature on students' aspirations of STEM majors in the Southeast Asian context in general, and in the developing world (like that of Cambodian upper secondary school) in particular.

To reiterate, the current study is unique in terms of its two main characteristics. First, the current study employed an explanatory sequential mixed method approaches in repeated cross-sectional designs to track students from the upper secondary school level to their prospective choice of STEM major in higher education. The study investigated the effects of tracking on time-varying covariates that influence students' choice of STEM major, as well as students' aspirations of STEM majors. Second, the current study employed a conceptual framework grounded in the four theoretical and conceptual models that supported the study's repeated cross-sectional investigation nature. These four conceptual models were utilised based on the theoretical foundations of holland's vocational choice theory, rational choice theory, and human capital theory.

On the other continuum, since upper secondary school year has been revealed to have significant influence on students' STEM choice in higher education and future career (e.g. Holmegaard, 2015; Ito & McPherson, 2018; Mean et al., 2018; Nugent et al., 2015; Ruse & Xu, 2018; Wang, 2013), the current study targeted the samples of upper secondary school students (rather than students who have already made a final choice and enrolled in higher education) and scrutinized how students who chose to attend in different tracks at upper secondary school were influenced in terms of their science outcomes (i.e. aspirations of STEM majors). Therefore, effective interventions to enhance students' STEM aspirations could be drawn and implemented in the very early grades of upper secondary school education. Table 3.9 below outlines the summary findings covering the main focus, data source(s), samples, outcome variables, and predictor variables of the extant study conducted in the Cambodian context.

Table 3.9: Summaries of prior studies (conducted in Cambodian context) on students' choice of major

Author(s) & Year	***Data Source***	***Sample***	***Outcome Variable***	***Predictors Variable***	***Main Focus***
Kao & Shimizu (2019)	Cross-sectional (Survey)	Freshmen at 9 higher education institutions (N=1281)	Dichotomous: science and engineering versus non-science and engineering	**Individual:** demographic, attitudes towards science, science and mathematics achievement, science and math self-efficacy, language proficiency **Family:** parents' education, parents' occupations, family income, siblings' majors **School:** teacher' intention, tracking system	Factors influencing students' choice of science and engineering majors in higher education
Eam et al. (2019)	Cross-sectional (Survey)	Freshmen at 15 higher education institutions (N=2016)	Dichotomous: STEM versus Non-STEM	**Individual:** demographic, self-efficacy, career prospect **Family:** working status, importance of science and technology, career knowledge, father's education **High School and university:** tracking, grade, achievement in science and math, time spent, perceived quality of teachers	A quantitative look at the correlates of choice of STEM majors among Cambodian freshmen
Kao (2019a)	Cross-sectional (National data from MoEYS database)	Students who applied for scholarship (N=1000)	Dichotomous: STEM versus Non-STEM	**Family:** Family Socio-economic Status (SES) (Measure on the household poverty score using the twenty-nine questions)	The influence of family SES and choice of STEM majors among scholarship students
Eng & Szmodis (2019)	Cross-sectional (Survey and classroom observation)	15-year-old students (N=100)	STEM interest scale	**Individual:** gender, attitudes toward science and math, perceived importance of science and math, **Family:** parents' supports in science and math **School:** teacher support, extra classes in science/math, lab utilization	To measure STEM interest and correlates among Cambodian secondary school students
Poeu (2017)	Cross-sectional (In-depth, biographical interviews)	University students (N=31)	Choosing a particular university major	**Family:** family context (resource, structure and dynamic, residential background) **University:** university experience (area of study, academic performance), person-situation interaction	Understanding young Cambodian people's decision making about university majors.
Pen (2011) (Unpublished Master's Thesis)	Cross-sectional (Survey and Structured interview)	Upper secondary (Grade 12th students) (N=175)	Choosing a particular university major	**Individual:** achievement, interest, gender, labour market understanding **Family:** parents' occupations, parents' education, family income, parents' intention **Institution:** teachers, tracking, admission process	To investigate the factors that influence the students' aspiration on their choice of majors in higher education

3.6 Synthesis of the literature

Synthesis of the extant international and local literature reveals that a number of factors involving in the complex process of students' choice of majors in general, and their choice of STEM majors in particular. Previous studies have thrown several implications for further examination. First, the decision to pursue a STEM major is not a one-time decision, but an on-going process that begins in upper secondary school education (Holmegaard, 2015; Ito & McPherson, 2018; Lee, Min, & Mamerow, 2015; Lent et al., 2018; Lent, Lopez Jr, Lopez, & Sheu, 2008; Mean et al., 2018; Nugent et al., 2015; Palmer, Maramba, & Dancy, 2011; Ruse & Xu, 2018; Wang, 2013). Since extant studies are cross-sectional of their kind, a repeated measures cross-sectional designs is vital to further delineate how the factors explain the students' choice of science track, and how the study track influences students to further transition into a STEM major in higher education throughout their time at upper secondary school. Put simply, despite a growing body of research describing the myriad factors that influence whether or not a student chooses a STEM major, little research has explored the lasting effects of such factors, which necessarily requires panel data analysis of upper secondary school and higher education nexus. In other words, not many research studies have examined the matriculation of the students from the science track at upper secondary school into STEM majors in higher education (Kao & Shimizu, 2019; Moakler & Kim, 2014; Ruse & Xu, 2018).

From an analytical perspective, employing a method which could account for testing the effects of the predictors when students are nested in different classes of upper secondary school is inevitable. Research on STEM education represents substantial empirical efforts to form a better understanding of the underlying factors that influence students' choice of STEM majors. However, few academic studies have dealt with the very first step of STEM participation: why students choose STEM majors. The primary focus of contemporary research is based on national samples revolves around students who have already chosen STEM majors (e.g., Eam et al., 2019; Eng & Szmodis, 2016; Kao & Shimizu, 2019). Aside from the imperative need to add to the empirical knowledge on STEM enrolment, studies in this vein have also called for a new theoretical framework that holistically captures the supports and barriers affecting upper secondary school students in choosing a major. Although these investigations are well grounded in prior literature, their conceptual consideration provides limited insight, and does not explicitly account for the developmental and longitudinal nature of students' interest in, and intention to study, a certain major in higher education. Thus, this study drew on a theoretical model with an intentional emphasis on the upper secondary/post-secondary nexus of the STEM pathway, which accounts for the longitudinal nature of STEM uptake. Also, extant studies have mostly voiced from the Western world. Hence, there is a need to extend research to other subgroups that are underrepresented in STEM, such as Southeast Asians in general and Cambodians in particular.

3.7 Conceptual framework of the current study

Facts do not exist independently of an explanatory framework. As such, drawing on the synthesis of the theoretical and conceptual models, the theory that the researcher used in the current study is rooted fundamentally in the Social Cognitive Career Theory (SCCT) and other well-developed models. In simple terms, the conceptual framework for the current study was developed by synthesizing the constructs of SCCT (Lent et al., 2002), the making of engineers and scientists model (Woolnough, 1994a), students' choice of academic majors choice model (Hu, 1996), and the STEM transfer model (Wang, 2013; 2017; Wang & Lee, 2019). (See Figure 3.2 for details.)

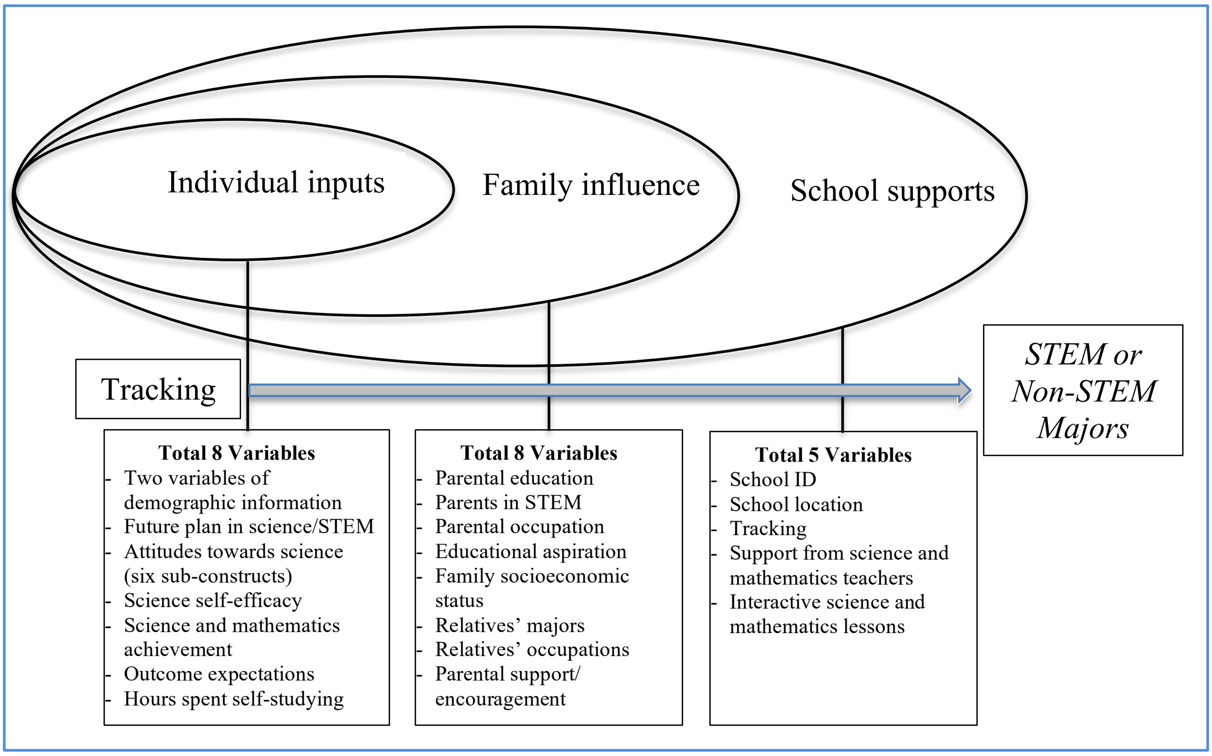


Figure 3.2: Conceptual framework for the current study

The lens of the synthesized model and the extant literature indicate that individual input (ability, attitudes, etc.), family influence (advice, financial support, etc.), and upper secondary school supports (learning experiences and support etc.) are key constructs to be investigated in the theory. Applying this concept to this study, the researcher posited that the independent variable(s) of the three dimensions of individual input, family influence, and upper secondary school support could influence or explain the dependent variable of students' transition from the upper secondary school science track to STEM majors in higher education. Figure 3.2 illustrates the holistic picture of the conceptual framework of the current study.

It should be noted again that the current study used the synthesized conceptual framework to address one main research objective; that is, to quantitatively examine the effects of tracking and the three dimensions (i.e. individual input, family influence, and upper secondary school support) on students' choice of STEM majors in higher education in Cambodia. Next, the study discusses the variables and their indicators (as synthesized from the literature review through the lens of the conceptual framework).

Dependent variable: For the analysis, within the individual dimension, the dependent variable (i.e. choosing a science track and majoring in STEM) was measured. The STEM majors in this study consisted of two items: *whether students are considering in a STEM field in university and asking students about the specific major they want to pursue*. According to the synthesized list of majors (see Appendix 1), researcher then classified the majors listed by the respondents into two broad fields of STEM and non-STEM majors. To reiterate, the list resulted from the synthesis of the contextual category of MoEYS (2009, 2016b, 2020c), the classification of STEM majors by the National Center for Education Statistics (NCES), and the classification of STEM majors by several prior studies (i.e. Chen, 2013; Chen & Weko, 2009; Crisp et al., 2009; Green, 2007; Ulicna & Royale, 2015; Wang & Lee, 2019).

Independent variables: The total number of independent variables (excluding the demographic variables) in the two-sections questionnaire consisted basically of eight key constructs. The study further classified these constructs into specific variables after exploratory factor analysis with principal axis factoring and Varimax and Keiser normalization in rotation. Each construct contained from 2 to 35 items, measured by a 1–4, 1–5, and 1–6-point Likert scale (see Table 3.10 for details). Measurements of the variables were developed based on current empirical investigations, with some modifications to fit the study's context, as well as the results of the pilot study. Overall, most of the tested variables were psychometric and perceptual measures.

Table 3.10: Details of the dependent and independent variables

Dimensions	Key constructs	Item Description	Factors loaded	Sources
Dependent Variable	STEM major (2 item) (List down the major and coded into STEM or Non-STEM)	Would you major in STEM or non-STEM at university? What is your major choice in higher education? Write the major.	1	Synthesis of the academic major by Chen, 2013; Chen & Weko, 2009; Crisp et al., 2009; Green, 2007; MoEYS, 2009, 2016b, 2020; Ulicna & Royale, 2015)
Independent Variables				
Individual	Academic achievement (10 items) (1-5 Likert Scale) (1=Poor, 5=Excellent)	Mathematic grade; Physic grade; Chemistry grade; Biology grade; Earth-environmental science grade; Khmer literature grade; History grade; Geography grade, Moral civics grade, English grade	1	Developed based on (MoEYS, 2018b)
Individual	Attitudes towards science (35 items) (1-5 Likert Scale) (1=Strongly disagree, 5=Strongly agree)	I like science practical work because I do not know what will happen; I would like more practical work in my science lessons; Practical work in science is good because I can work with my friends; Practical work in science is exciting; I like practical work in science because I can decide what to do myself; We learn science better when we do practical work; I look forward to doing science practical work; Science is one of my best subjects; I learn science quickly; I get good mark in science; I am just good at science; In my science class, I understand everything; I feel confidence when doing science; Science and technology are helping the poor; Science and technology make our lives easier and more comfortable; The benefits of science are greater than harmful; Science and technology are important for society; There are many exciting things happening in science and technology; Science lessons are exciting; Science is interesting for me; I like science better than many other subjects at school; I would like to do more science at school; I look forward to my science lessons; I like to visit science museum; I like watching science program on	6	Attitudes towards Science Adapted from Kind et al. (2007) in line with with Fraser (1981)

		TV; I like reading science magazine and books; It is exciting to learn about new things happening in science; I have participated in science festival/STEM festival; I have participated in the event on STEM bus; I have participated in science and technology competition; I have participated in science and mathematics club.		
School	Interactive science and mathematics lessons (7 items) (1-4 Likert Scale) (1=Almost never, 4=Very often)	I talk to my classmates about how to solve problems; I use information to support my answers; I learn from my classmates; My teachers encourage me to ask questions; My teachers ask me to give reasons for my answers; I repeat experiment to check results; My teachers ask open-ended questions that make me think.	1	Adapted from Standards based practices (Scantlebury, Boone, Butler Kahle, & Fraser, 2001)
Individual	Science and mathematics self-efficacy (8 items) (1-5 Likert Scale) (1=Strongly disagree, 5=Strongly agree)	I can do excellent job on mathematics and science assignments; I can master mathematics and science class skills; I can understand difficult mathematics and science class; I can understand difficult mathematics and science texts; I can do excellent job on mathematics and science tests; I can do well in courses related to science and engineering majors; In science classes, even if the work is hard, I can learn it; I can do even the hardest work in science classes if I try.	1	Adapted from Pattern of Adaptive Leaning Scale (PALS)-ability to learn in science class (Midgley et al., 2000); (Fouad, Smith, & Enochs, 1997)
Individual	Science and mathematics outcome expectations (7 items) (1-5 Likert Scale) (1=Strongly disagree, 5=Strongly agree)	If I get good grade in mathematics and science, my parents will be pleased; If I do well in mathematics and science, I will be better prepared to go to college; If I do well in science classes, I will do well in upper secondary school; If I take mathematics course, then I will increase my grade point average (GPA); If I learn mathematics well, then I will be able to do a lot of different type of careers; If I get good grade in mathematics and science, my friends will approve of me; If I take a lot of mathematics courses, then I will be better able to achieve my future goals.	1	Adapted from Fouad, Smith, and Enochs (1997)
Family	Parental/Social Encouragement and support (7 items) (1-5 Likert Scale) (1=Strongly disagree, 5=Strongly agree)	Male students are encouraged to participate in science; Female are encouraged to participate in science; My teachers encourage me to participate in science; Society environment encourages me to participate in science; My classmates/friends encourage me to participate in science; My parents/family encourage me to participate in science; I will be highly appreciated if I am majoring in one of the STEM fields.	1	Adapted and modified based on Stein (2012)

Individual	Future plan in science (5 items) (1-5 Likert Scale) (1=Strongly disagree, 5=Strongly agree)	I would like to study science related majors at university; I would like to study more science in the future; I would like to have a job working with science; I would like to become a scientist; I would like to become a science teacher.	1	Attitudes towards Science Adapted from Kind et al. (2007) in line with Fraser (1981)
School	Science and mathematics teachers' support (12 items) (1-6 Likert Scale) (1=Never, 6=Always)	My science and mathematics teachers show me how to do things; My science and mathematics teachers help me to solve problem by giving me information; My science and mathematics teachers make it okay for me to ask questions; My science and mathematics teachers tell me about how to do well on task/assignment/homework; My science and mathematics teachers treat me fairly; My science and mathematics teachers tell me nicely when I make mistakes; My science and mathematics teachers explain thing that I do not understand; My science and mathematics teachers tell me I did a good job when I have done something well; My science and mathematics teachers care about me.	1	Adapted from Child and Adolescent Social Support Scale (CASSS)-12 item scale (Malecki & Demaray, 2002; Malecki, Demaray, & Elliott, 2003)

The individual, family, and school dimensions are basic, yet core, components of the conceptual framework of this current study. A large body of literature on the determinants of students' choice of STEM majors has confirmed that in addition to individual preferences and personal ability and attitudes, other factors affect their choice as well (e.g. Chen, 2013; Myeong & Crawley, 1993; Paik & Shim, 2013; Woolnough, 1994a). This current study used these three dimensions as a lens to systematically and specifically examine each element of the focused research questions based on mixed methods data. Due to time constraints, although the current study could not longitudinally scrutinize the issue, the repeated cross-sectional and pragmatic investigation of the realm of theoretical and philosophical knowledge stance provides a holistic picture of the issue. Put simply, the issue of the students' track choice in upper secondary school level, and their academic transition into STEM majors in the higher education nexus of Cambodia are pragmatically portrayed through an explanatory sequential mixed method approaches.

3.8 Logical connection from conceptual model, literature review, and measurement

Figure 3.3 depicts the logical connections among the synthesis of the theoretical and conceptual models, the literature review and the methodology, and specifically the measurement of the variables. The theoretical foundation for choice of major and the conceptual models for choice of STEM majors lay the framework for the literature review, which provides the basis for discussing the variables and their measurements. The theoretical and conceptual models conclude with the dimensions and constructs to be covered. Through this lens, the conceptual framework limits the variables under each construct. The literature review offers a comprehensive, empirical discussion and addresses the measurement of the variables. The following chapter delves into the details of measurement.

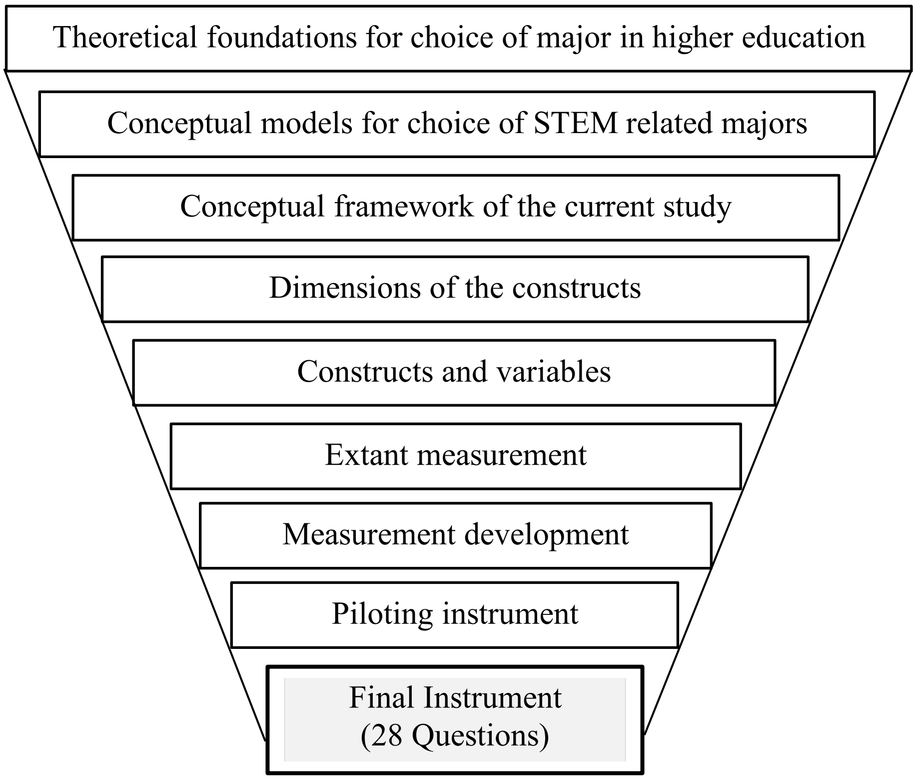


Figure 3.3: Logical flow from theoretical to conceptual models, literature, and measurement

Previous and current chapters explore the *"why"* and *"what"* questions. The next chapter illustrates in detail the answer to the *"how"* question. Simply put, the coming chapter illustrates the study's overall design, samples, measurement, and analytical methods in order to answer the three specific research questions. Ultimately, the main objective of this current study is to investigate the effect of tracking system and other multi-dimensional variables that explain Cambodian upper secondary school students' transition from the science track to STEM majors in higher education.

CHAPTER FOUR: RESEARCH METHODOLOGY

The previous three chapters explained the question of *"why"* and "*what*" the current study is about. This chapter, thus, answers the question of *"how"* the study was conducted in order to respond to the *"what"* question. Chapter four starts with a description of overall design of the study, justifications for selecting the research context and its descriptions, the procedures for samples selection and their characteristics, and the research site. The chapter then delves into the details of the data collection procedures, the instrument and measurement of each variable, and briefly summarizes the analytical tools employed to achieve the output for the specific research objectives mentioned in Chapter one. The chapter concludes with the figure of the study's analytical framework.

4.1 Philosophical and methodological foundations

According to Slife and William (1995), *philosophical foundations* (*worldview* [Guba, 1990], *paradigms* [Lincoln, Lynham, & Guba, 2011; Mertens, 2010]) remains largely hidden in research, even though its influences on the practices of research need to be identified. Thus, it was suggested that philosophical ideas should be made explicit for the larger philosophical worldviews they espouse (Creswell & Creswell, 2018). Philosophical worldviews help to explain why certain kind of (i.e., quantitative, qualitative, or mixed methods) approaches are employed in research being conducted (Bryman, 2016). In this regard, this section elaborates on the philosophical foundations that the current study employed to investigate the issue so as to draw conclusion and implications.

4.1.1 Worldview: The pragmatism of the mixed methods approach

The *worldview, philosophical foundations, or paradigms* employed in this study take a *pragmatist* theoretical stance. To understand why the current study adopted the pragmatism of the mixed methods approach, it is significant to discuss the different philosophical foundations frame each research approach. This sub-section briefly discusses the three main philosophical foundations—post-positivist, constructivist, and pragmatist.

First, the *post-positivist* view challenges the traditional notion of the absolute truth of knowledge, and recognises that people cannot be positive about claims of knowledge when studying human behaviours and actions (Creswell & Creswell, 2018; Smallbone & Quinton, 2004). The post-positivist worldview focuses on: the causes that influenced the outcomes; the intent to reduce an idea into a small, discrete set to test (i.e., variables that comprise hypotheses and research questions); the observations and measurements of the existing objective reality out there in the world (i.e., numeric measures of the observations and behaviour of the individuals); and the laws or theories that govern the world. Thus, to understand the world, these aspects need to be tested or verified and refined. To reiterate, the worldview involved is significant, as the philosophical worldview assumptions is related to the research design and specific method (or procedure of research) that translate the approach into practice. Post-positivist assumptions hold true for quantitative approaches since they support theory-driven stance (Creswell & Creswell, 2018).

Another worldview is constructivism or social constructivism, which originated from Berger and Luckman's (1967) *Social construction of reality* and Lincoln and Guba's (1985) *Naturalistic inquiry*. Constructivists believe that people seek to understand the world in which they live and work through the development of the subjective meanings of their experiences towards certain objects. With that herein, the goal of the research study is to rely as much as possible on the views of the situation or condition being examined based on the perspective of the participants. Researcher guided by a constructivist foundation tends to make sense of the meanings that others have about the world, rather than to be guided by a theory, to inductively develop a theory or pattern of meaning about a given situation (Creswell & Creswell, 2018). The constructivist worldview is seen as an approach to qualitative research.

The pragmatic worldview derives from the work of Peirce, James, Mead, and Dewey; it emphasizes on the research problem and question, rather than the method. The researcher uses all approaches available to understand the problem (Creswell & Creswell, 2018), and tries to apply what works in order to solve it. Pragmatists do not see the world as an absolute unity; rather they agree that research always occurs in social, historical, and political contexts. They look to the "what" and the "how" so as to conduct research based on the intended consequences.

In this regard, as guided by the theoretical framework—and because the factors involved ultimately have different effects on students' aspirations of STEM majors upon graduating from upper secondary school—it was crucial to employ an explanatory sequential mixed methods approaches. In quantitative methods researchers have tested theories by specifying narrow hypotheses and collecting data to support or to refute them (Creswell & Creswell, 2018). In qualitative approaches, researchers seek to understand a phenomenon through students' perceptions. With that said, it was essential to incorporate both quantitative and qualitative approaches to determine the most significant predictors for Cambodian upper secondary school students' science outcomes (i.e. their aspirations of STEM majors) through the conceptualized lens of empirical theoretical models for students' choice of STEM majors. Additionally, it is crucial to ensure that students' lived experiences are described in their own words. All in all, the current study entailed an explanatory sequential mixed method approaches to investigate the relationship between theory and research; which the accent was placed on testing the theory, and embodied a view of social reality as an external, objective reality, as well as the students' subjective explanations and opinion (Bryman, 2016; Cohen & Morrison, 2007; Creswell & Creswell, 2018). Therefore, this study was guided by the pragmatism of the mixed method approaches.

4.1.2 Brief methodological framework: The logical flow of the study

The brief methodological framework illustrates the central methodological and conceptual principles on which this study is based, how it logically relates to the current study's specific research questions, and ultimately its main question. Simply illustrate, this study focuses on how the tracking system between the science and social science tracks and multi-dimensional factors, influence Cambodian upper secondary school students' transition to STEM majors in higher education. Chapter 3 (literature review on choice of STEM majors and conceptual framework) covers the details of the conceptual framework.

The framework included the investigations of the effects of multi-dimensional factors—individual (e.g., academic achievement, attitudes towards science, science and mathematics self-efficacy, science and mathematics outcome expectations, science and mathematics achievement), family (e.g., parents' education, occupations, encouragements and support), and upper secondary school (e.g., support from science and mathematics teachers, interactive science and mathematics lessons, and institutional demographic variables)—on upper secondary school students' choice of the science track and aspirations of STEM majors. These multi-dimensional factors comprise the synthesis of extant local and international literature, as well as policy initiatives that foster students' interest in STEM majors. Figure 4.1 provides a brief overview of methodological framework and its coherence with the key research questions that guided the current study.

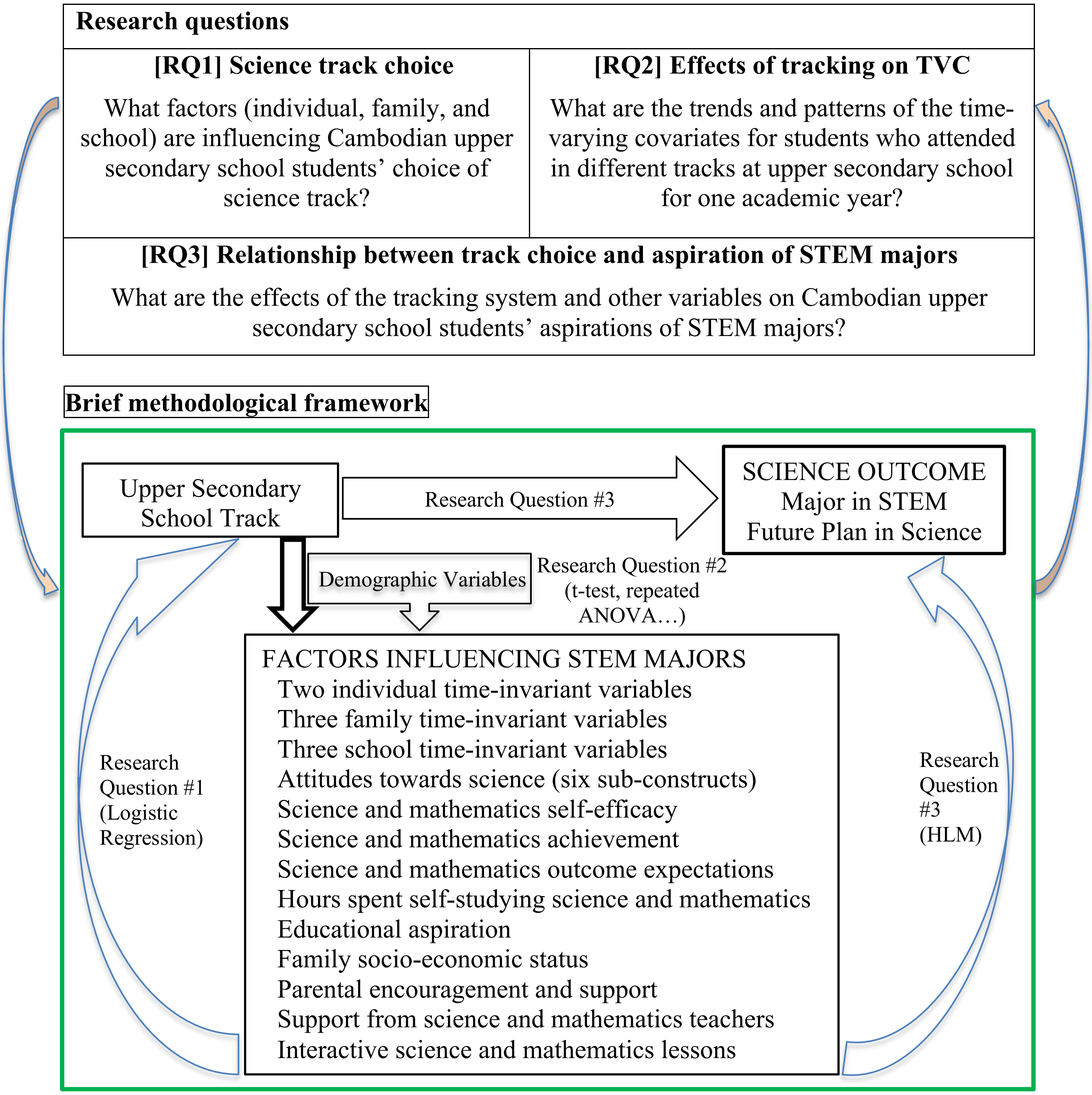


Figure 4.1: Methodological framework of the study and its coherence with research questions
Source: Developed by the author of the present study

As the nature of the repeated cross-sectional design suggests, The study examines the effects of the three multi-dimensional factors (measured in the first wave of data collection) to answer research question 1: factors that explain students' choice of the science track (discussed in Chapter 5). The second wave of data collection served two main purposes: investigated the trends and patterns of changes in the time-varying covariates—comparing observation 1 with observation 2 (discussed in Chapter 6)—and the effects of the tracking system (the science versus the social science track) and the three dimensions variables on grade 11th upper secondary school students' aspirations of STEM majors (discussed in Chapter 7). Simply explain, the second wave measurement of the repeated data served as the analytical purposes in responding to two research questions. That is, measuring how a different tracks influenced the time-varying covariates (which are included in the conceptual framework of the current study), and how different science and social science tracks and the other multi-dimensional factors prospectively influenced Cambodian upper secondary school students' aspirations of STEM majors in higher education.

4.2 Overall design

Drawing on the philosophy of pragmatism, this study employed an *explanatory sequential mixed method* approaches with repeated measures to answer the three focused research questions *(Pragmatist » Mixed method Approaches » Correlational Method » Repeated Design of QUANTITATIVE approach » Qualitative approach)*. By this token, this study is a *correlational* research that uses a *repeated measures design* to examine the behaviour of changes in the variables (Creswell & Creswell, 2018), given the result of being in a different track and predicting the students' aspirations of STEM majors in higher education from their upper secondary track. This approach—which involved two distinct phases—allowed the researcher to gain insight into factors surrounding the students' choice of the science track, the effects of different tracks, and their aspirations of STEM majors. Figure 4.2 outlines the study design and highlights the phase, procedure, and product of each component. In the first phase, with the QUANTITATIVE method, the researcher panelled the data from Cambodian upper secondary school students to collect information on their individual level, family environment, and school support from the beginning of grade 11th to the end of grade 11th. The repeated measures design tracked individuals over time by gathering details throughout one academic year. The quantitative design is advantageous because it allowed the researcher to cull large amounts of data necessary to perform statistical analyses, and to determine the significant predictors, which informed the prospective participants for qualitative phase as well as the types of questions asked. This design intended to have the qualitative data to help explain initial results of the quantitative survey in greater detail.

Figure 4.2: Detailed outline of the study design

Phase	Procedure	Product
Quantitative Data Collection	• Panel data with grade 11th students • First wave (N=752) • Second wave (N=700)	• Numerical data from • First wave (N=752) • Second wave (N=700) • Consolidate data (N=700)
Quantitative Data Analysis	• Data screening • Factor analysis • Frequency • Mean difference • Logistic regression • HLM analysis	• Descriptive statistics • Factor loadings • Significant difference • Difference by observation • Significant predictors
Case Selection	• Purposefully selecting students • Gathering students' contact • Developing interview instrument	• Case (N=25) selected • Social network for online interview (Facebook messenger) • Interview protocol
Qualitative Data Collection	• Approach students • Online interview • Online focus group interview (N=10) • Online interview (N=15)	• Focus group discussion records (4) • Interview records (15) • Transcripts (19)
Qualitative Data Analysis	• Coding and analysis for themes • Category coding and thematic analysis	• Codes and themes • Similar and different themes and categories • Qualitative explanation
Integration of Quantitative and Qualitative Results	• Triangulation of results • Interpretation and explanation of the quantitative and qualitative results	• Discussion of the results • Implications • Further research

Adapted from Ivankova and Stick (2007)

Furthermore, studies of this kind often collect information during (and alongside) parallel processes and at different levels (micro, meso, and macro). The underlying idea is that an individual's life course can only be understood if (or when) it is placed into the context of the trajectories of one's social life. Because change at the "macro" level could potentially affect the life course of an individual, the life course should not be isolated from the *"situation"* in which it is set. In other words, these data make it possible to analyze the developments within the institutional, cultural, and social contexts in which an individual's life course unfolds. By focusing on events and transitions in individual lives, the interactions between actions and structures can be closely observed. Thus, this panel study is concerned with illuminating social changes to deepen understanding of causal influences over time. The design is somewhat better for dealing with the problem of ambiguity about the direction of causal influence that plagues cross-sectional research (Bryman, 2016).

In the second phase of the study, qualitative approach through semi-structured interviews, using coding and thematic analysis approach, was employed. The goal of the semi-structured interviews was to give the quantitative participants an opportunity to express their personal views and feelings in their own words, which allowed the refinement of the survey results and to determine alternative predictors for students' choice of the science track and their aspirations of STEM majors. The study employed both the semi-structured interviews and the focus group discussions. There were three justifications for this follow-up focus group discussion. First, this method promoted discussion among group members to elicit deeper viewpoint and insight. Second, focus group discussion increased the understanding of the students' view and feelings by gathering common expressions and in-dept details within a short time period. Lastly, the method enhanced the accessibility of the participants to the online interview. Some students did not have access to the Internet services; thus, they were able to join their friends during the focus group discussion.

4.3 Research design

As briefly stated earlier, this study employed an explanatory sequential mixed method approaches with a panel study design to examine the factors that explain Cambodian students' transition from the science track to STEM majors in higher education. This section details the approach used in this study. The chapter begins by explaining the context of the study, the sampling and samples the data were gathered from, the instrument used, and how the data were analyzed for each research question.

4.3.1 Research context

This study was conducted in Phnom Penh, Kampong Cham, and Battambang provinces (from among the 25 capital and provinces of Cambodia). Table 4.1 illustrates the landscape of upper secondary school students in the three selected provinces from 2012 to 2019 in the aspects of total enrolment and the percentage of students that passed the grade 12^{th} national examination. In a similar trend to the country level, the proportion of grade 12^{th} students that passed the baccalaureate examination before the educational reform in 2014 was very high in the three capital and provinces where this study was conducted. As can be seen in Table 4.1, from about 80% to 94% of students tend to pass the examination. However, this figure dropped dramatically in the first year following the reform in the baccalaureate examination. This number fell to about 20% in Battambang and about 33% and 25% in Phnom Penh and Kampong Cham, respectively. The percentage of the students that passed the examination has begun to rise gradually over the past few academic years. The proportions in Phnom Penh, Kampong Cham, and Battambang were about 57%, 67%, and 65%, respectively.

Table 4.1: Number of grade 12^{th} students and the percentages that passed the baccalaureate examination in the three sampled provinces

Year	**Phnom Penh (PP)**		**Kampong Cham (KC)**		**Battambang (BTB)**	
	Total Students	Percentage Passed G.12	Total Students	Percentage Passed G.12	Total Students	Percentage Passed G.12
2012	19,716	94.25	9619	90.32	7,070	80.52
2013	18,887	95.09	9131	87.98	3,358	86.65
2014	16,794	33.17	8401	25.18	5,483	19.68
2015	16,153	58.81	5732	48.74	5,133	54.37
2016	17,046	62.61	5842	52.17	5,551	57.99
2017	18,617	60.04	5870	56.49	6,195	60.13
2019	21,947	57.88	7950	66.72	7,165	64.63

Source: MoEYS (2019d)

4.4 Quantitative design and methods

4.4.1 Research sampling and samples

This study employed multi-stage cluster random sampling technique to select the samples. To ensure true representation of the population, 25 provinces in Cambodia were ranked according to the statistics on grade 12th students' enrolment for the academic year 2017–2018 (Department of General Education, MoEYS, 2017). On a random basis, one province each from the highest and lowest category were selected. Two provinces in the middle category (with enrolment above 5,000), and two provinces in the lowest category (with enrolment below 5,000) were selected. Therefore, six provinces were primarily and randomly selected (see Figure 4.3).

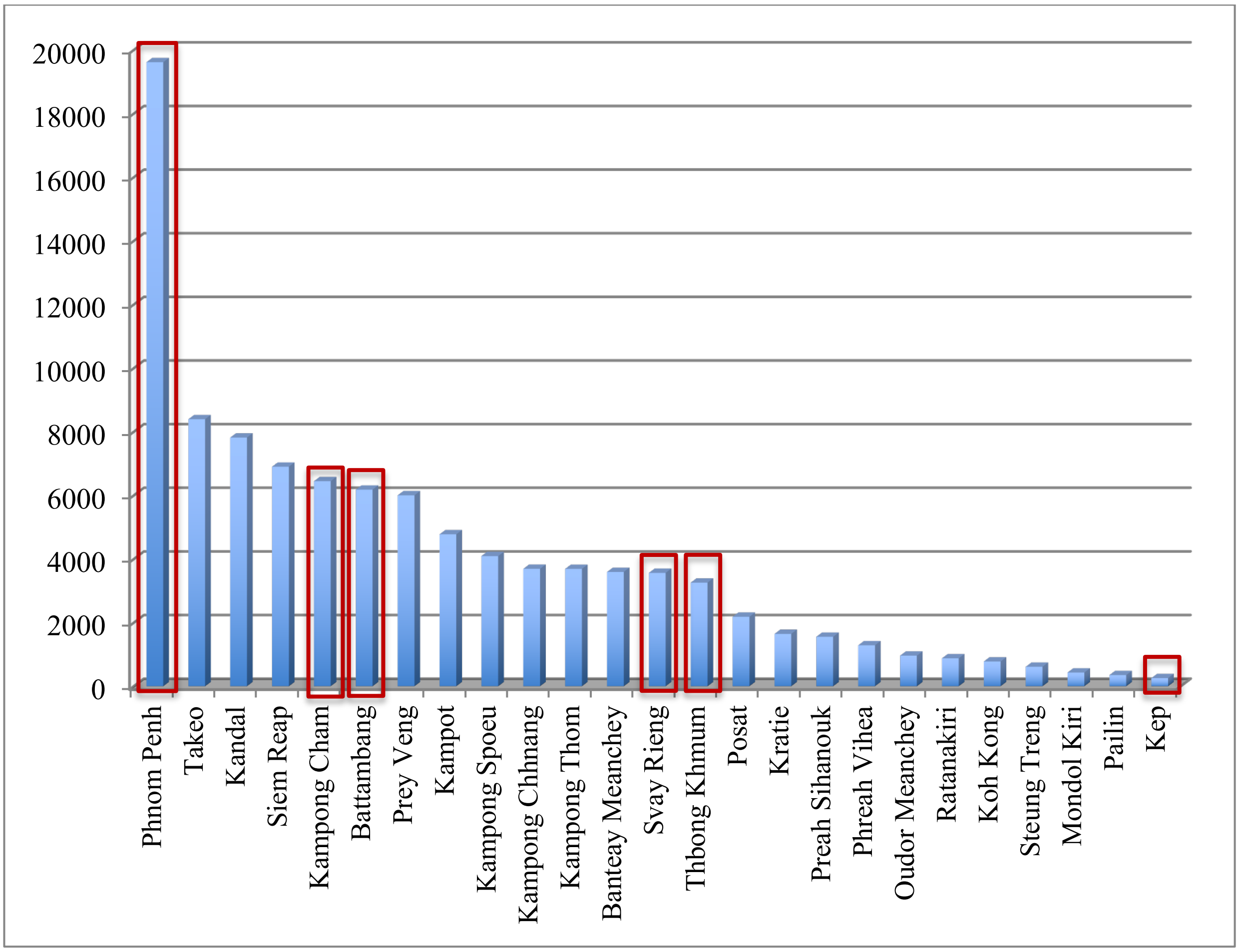


Figure 4.3: Number of grade 11th students in the academic year 2017–2018

For the next stage of sample selection, the researcher thus utilized the second justification, which was the percentage of students' enrolment in higher education in the six provinces marked with a red outline (in the figure above). Finally, based on the statistics from 2018–2019 on the share of students' transitioning from upper secondary school to higher education, three provinces: one from the highest percentage, one from the middle category, and another from the lowest group were selected to be the target provinces. The second justification was that the selection of the three provinces was based on the existence of the so-called new generation (NGS) upper secondary schools in those provinces. As could be seen in Figure 4.4, Phnom Penh, Kampong Cham, and Battambang provinces were selected (the first stage of the sampling technique, to identify the research site).

The second stage involved choosing schools in the targeted provinces. Schools in each province were then divided into two strata: urban and rural/non-urban schools. Also, due to time and accessibility constraints, NGS, schools in the centre of the province or capital city, schools about 40–50 kilometer from the city centre or province and locate along the main national road were randomly selected. From this selection justification, nine upper secondary schools (four in Phnom Penh, three in Kampong Cham Province, and two in Battambang Province) were selected.

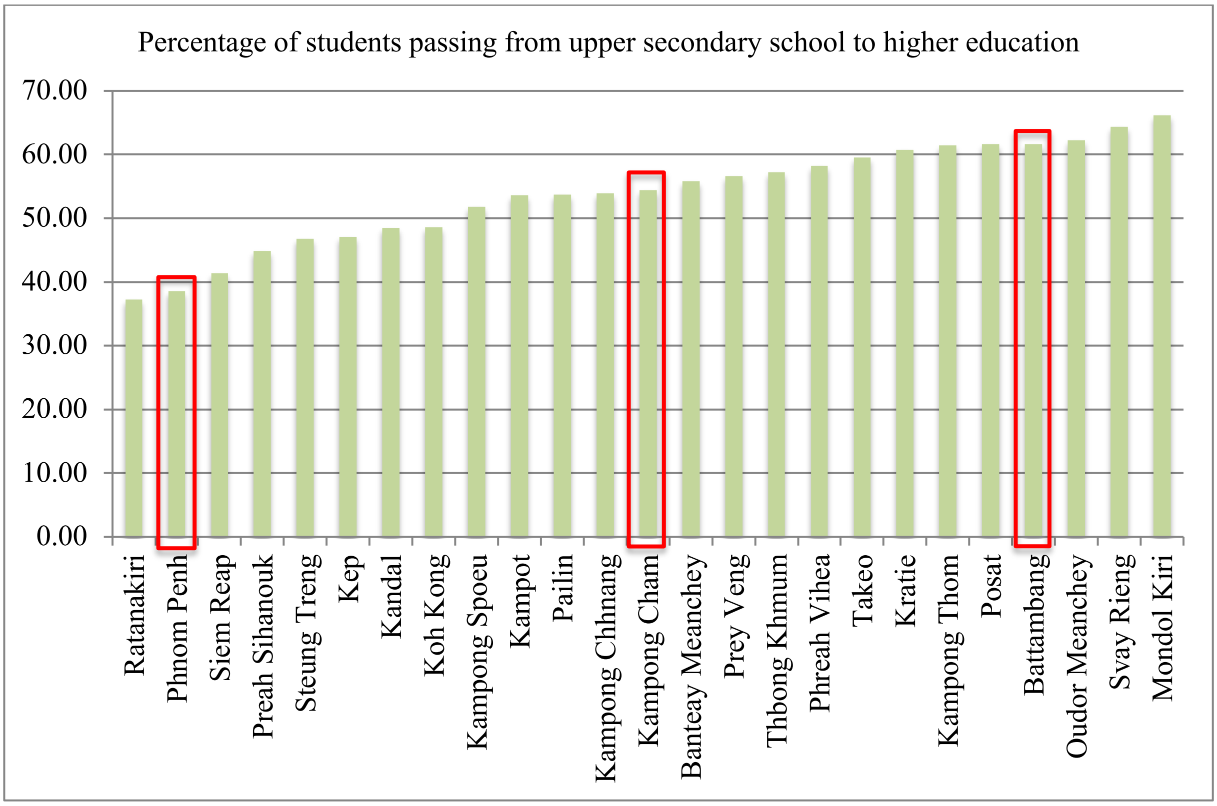


Figure 4.4: Percentage of students that graduated from upper secondary school and went on to higher education in the selected provinces

Furthermore, for the purpose of group comparison, the selected schools needed to have approximately equal proportions of students in the science and social science track. Thus, each stratum was then further divided into two sub-strata (i.e. science and social science track classes). To select the class, the researcher requested a list of the grade 11th students by class. Consequently, the last stage of random technique was to select one class each from the sub-strata for the survey. However, because in the two NGS, there were only science classes and there were only three and two classes, respectively, all classes were selected. All students in each randomly chosen class were cluster-selected to be the samples. Finally, students from 21 classes from nine upper secondary schools in three provinces were selected to be the samples for the repeated cross-sectional survey.

There were two waves of data collection. In the first wave of data collection, there were 766 students participated in the survey. However, researcher removed 14 students who did not completed the questionnaire and/or did not provide the personal information needed for follow-up survey. Thus, 752 usable samples remained from the first wave, which the researcher followed up with for the second wave, conducted six months after the first. In this second wave, 700 students took part (which was equal to 93.09% of the first wave's figure) and completed the second wave survey questionnaire.

In a panel design of the repeated cross-sectional approach, *panel mortality* is a key problem. There are a few anecdotes to explain the loss of samples. First, dropping out of upper secondary school is a major concern (from interview with the students). Most students, especially those from the non-urban areas, dropped out of school to find work in Phnom Penh or other provinces. Second, because the second wave data collection was carried out after the second semester examination and it was during the hot season in Cambodia, a number of students were absent. Being aware of this issue, the researcher first needed to contact the school principals or the people in charge of data collection, and asked them to kindly inform to the students about the date of data collection and to invite them. Also, the researcher needed to go to one target school at least two times to administer the survey to the students who missed out (excluding those who had dropped out of school) for the first meeting of the data collection session. Due to this, there was only about 7% loss of the sample from the first to the second wave. See Table 4.2 for details on the samples from the nine upper secondary schools that participated in the two waves data collection.

Table 4.2: Description of the quantitative sample sizes

No.	Schools	Usable First Wave	Usable Second Wave	Retention Rate
1	Upper secondary school 1	102	93	91.18
2	Upper secondary school 2	75	66	88.00
3	Upper secondary school 3	77	73	94.80
4	Upper secondary school 4	100	98	98.00
5	Upper secondary school 5	54	54	100
6	Upper secondary school 6	78	64	82.05
7	Upper secondary school 7	82	77	93.90
8	Upper secondary school 8	104	99	95.19
9	Upper secondary school 9	80	76	95
	Total Samples (766)	***752***	***700***	***93.09***

Table 4.3 below summarizes the brief descriptive statistics by characteristics of the samples who participated in this current study. Most of note, overall male, science track, and non-urban students outnumbered their female, social science, and urban counterparts. In the first wave, 56% of the sample was female compared to 44% that of male participated in the survey. This figure did not change much during the second wave data. Cross-tabulation by study track revealed more participants from the science track than the social science track. One reason to explain this phenomenon was that although cluster random sampling was employed, in the new generation schools (NGS) (one in Phnom Penh and another in Kampong Cham Province) only offered the science class. Since their main focus is to strengthen science (or so-called STEM) education from upper secondary school, these two upper secondary schools did not provide social science classes. Also, about 20% of the students were from NGS and about 79% from traditional upper secondary schools. From the locality perspective, there seems to be quite a balanced between students from the urban and the non-urban parts of the country participated in the study. Put in statistical terms, about 47% of the students from the urban area (Phnom Penh) and about 52% from the non-urban zones (the two provinces) participated in the study. This provides a good foundation for locality comparison in further analysis.

Table 4.3: The profiles of the samples by characteristic

Variables	First Wave		Second Wave		Retention Rate
	N	%	N	%	%
Gender					
Male	331	44	310	44.3	93.66
Female	421	56	390	55.7	92.64
Study Track					
Science	464	61.8	443	63.3	95.47
Social Science	288	38.3	257	36.7	89.24
School					
New Generation School	154	20.5	152	21.7	98.70
Traditional School	598	79.5	548	78.3	91.64
Geographical Origin					
Urban	354	47.1	330	47.1	93.22
Non-urban	398	52.9	370	52.9	92.96

4.4.2 Characteristics of the sampled upper secondary schools

Upper secondary school 1, founded as a modern school in 1873 (and one of the first upper secondary school to have been established), is situated in the centre of Phnom Penh. It became as as college in 1905, and by 1936, it was upgraded to an upper secondary school. Currently two levels of general education are offered on campus: lower secondary and upper secondary. (This upper secondary school shares a campus with the so-called NGS, but the two schools have completely separate administrations, teachers, management staff, and other logistical arrangements). In academic year 2019–2020, there were about 3,600 students (including the lower and upper secondary levels). Interestingly, there were more students in the science track than in the social science track. There were about 647 grade 12th science track students, and 243 social science track students, divided into 16 classes and 4 classes, respectively. Since this is one of the oldest upper secondary school and located in the city, the school has many long-year experienced teachers. There seemed to be many students in each class (42–56). Overall, there were 245 upper secondary level teachers (89 female), among these, 40 (12 female) were science teachers and 12 (1 female) were mathematics teachers.

Located on the western outskirts of Phnom Penh, upper secondary school 2 has been operating since 1964. Uniquely, it is not only a general and technical upper secondary school, but also a resource school. It offers general education programmes, as well as technical and vocational education programmes, on campus. There were 2,567 students for academic year 2017–2018 (among them, 1,243 were female); this figure rose to about 2,830 for academic year 2018–2019 (among them, 1,439 were female). At the time of the first wave data collection, in grade 11th, there were 10 classes comprising 618 students in the science track and 4 classes made up of 303 students in the social science track. Although upper secondary school 2 has implemented the two-shifts system, there seems to be a lack of classrooms as a single classroom contained up to 65 students on average. According to the statistics from 2019, there were 116 teachers (45 of whom were female). Most noteworthy, there were 50 science teachers (14 of whom were female) and 13 mathematics teachers (one of whom were female); all of them held a bachelor's degree at minimum.

Upper secondary school 3 is located on the eastern outskirts of Phnom Penh and was founded in 1980. There were 687 (355 female) and 537 (298 female) students in academic year 2017–2018 and 2018–2019, respectively. This figure rose to 572 (323 female) students in academic year 2019–2020. In the most recent academic year, there were 4 classes of grade 12th science track students, and only two classes of socials science track students. However, this trend seems to have reversed completely. Although the usual policy is to promote students' interest in the science track, the number of classes in the science track has decreased to only 3, while the number of classes in the social science track has increased to 4. In this last academic year, there were 80 (27 female) teachers with a bachelor's degree and above who were teaching at the upper secondary level. More importantly, this school is the home to the so-called NGS. Since academic year 2017–2018, the school has been implementing the pilot project of NGS. However, the programme is still at the lower secondary school level (grades 7th, 8th, 9th). In academic year 2018–2019, there were six classes each for grade 7th, 8th, and 9th, respectively. To be enrolled in this new school, students need to pass the entrance examination which covers the subject of science (physics, chemistry, and biology), Khmer literature, mathematics, and critical thinking skills. Unlike the traditional upper secondary school in the system, students need to study full-time, from 7 in the morning to 4 in the afternoon. Since it is a three-year pilot project, the school became autonomous in academic year 2019–2020.

Located on the campus of the first upper secondary school, upper secondary school 4 is one of the pilot NGS and contains the 7th to 12th grades. The school was inaugurated on 23rd June 2016 as an NGS to implement STEM teaching and learning. The rooms in this school are equipped with teaching facilities and experimentation laboratories. Moreover, the teaching hours have been increased from 32 hours at traditional upper secondary school to 40 hours a week. Thus, the students have to take classes full-time, from morning to afternoon, Monday through Saturday. The teachers have also been incentivized by a bonus of about 150 USD, in addition to the regular salary of mainstream Cambodian civil servants. Statistically, there were 756 students in academic year 2017–2018; this number increased to 917 in academic year 2018–2019. At the time of the first wave of data collection, there were 3 classes of grade 11^{th} students, with an average of 35 students in one class. The three science classes were divided into physics, chemistry, and biology. There were about 40 teachers, among whom 16 were science teachers; all of them held a bachelor's degree at minimum.

Upper secondary school 5 is situated in the centre of Kampong Cham Province, about 130 kilometers from Phnom Penh. It shares a building with Kampong Cham Regional Teacher Training Centre, and was first established as an anuwath (practical) primary school in 1998. It was upgraded to a lower secondary school in 2012 and to an upper secondary school in 2015. Starting with only the grade 10^{th} in academic year 2014–2015, the upper secondary school 5 expanded to include two grade 11^{th} classes (Khmer literature and mathematics) in academic year 2015–2016, and two more classes (physics and chemistry) in academic year 2016–2017. In academic year 2017–2018, the school was upgraded to an NGS and offered a general education programmes to 427 (228 female) students and 402 (216 female) students in academic year 2018–2019. By the time of the first wave of data collection, there were only two grade 11^{th} science track classes with a total of 65 students (of whom 34 were female). In the most recent academic year, there were 31 teachers (20 of whom were female) 15 science teachers (10 of whom were female) and 6 mathematics teachers (2 of whom were female). All of them held a bachelor's degree and had at least 4 years of teaching experience.

Upper secondary school 6 is located about 30 kilometers along the national road from Kampong Cham to Phnom Penh. It was first established as a lower secondary school in 1966 and upgraded to an upper secondary in 1999. There were 1,740 students (982 of whom were female) in academic year 2017–2018. However, this number decreased to 1,691 students (932 of whom were female) in academic year 2018–2019. During the first wave of data collection, this upper secondary school had 131 (87 female) and 182 (102 female) grade 11^{th} students which were divided into 3 and 4 classes, respectively. On average, a single class had about 45 students. Currently, there are about 110 teachers (70 female) teaching at both the lower and upper secondary school levels. Among them, 12 are science teachers and 6 are mathematics teachers. Since, there are not enough teachers, although teacher who work at upper secondary school should hold a bachelor's degree, some current teachers only have an associate's degree. The teacher shortage—especially in science and mathematics—and teachers whose qualifications does not match with the requirements for their position—seem to be among the concerns that school have.

Also located along the national road from Kampong Cham to Phnom Penh, upper secondary school 7 is about 50 kilometers from Kampong Cham and about 80 kilometers from Phnom Penh. It was first opened in 1963 and it was completely destroyed during the Pol Pot regime. It was rebuilt in 1980 as a lower secondary school and was upgraded into an upper secondary school in 1993. Now it becomes the resource school. In academic year 2017–2018 there were 2,190 students; and the number of enrolment remained almost stable in academic year 2018–2019, when there were 295 science track students compared to about 49 social science track students. Although the school was operating under the two-shift system, the number of students within one class was also high (around 45 students per class). In the last academic year, there were approximately 90 teachers (among whom 41 were female). It is interesting to note that there were 23 science teachers (of whom 12 were female) and 13 mathematics teachers (one of whom was female). Most of them had more than 10 years of teaching experience, while other were just grade 12th graduates.

Upper secondary school 8 was first established as a lower secondary level II school, and was upgraded to an upper secondary school in 1989. It is located about 50 kilometers from Battambang Province's city centre. Once a graveyard in the 1960s, the area currently locates the upper secondary school, which enrolled 2,039 students in academic years 2017–2018, and 2,303 students in academic year 2018–2019. During the samples selection period, there were 279 science track students (divided into 6 classes) and 426 social science track students (divided into 6 classes). The conditions seemed to be crowded in a single classroom, as there were up to around 50–60 students per classroom. Currently, the school seems unconcerned with the teacher shortage, as in the case of upper secondary school 7, where there were about 73 teaching staffs (all with a bachelor's degree) among whom 33 were science teachers (among whom 10 were female) and 14 were mathematics teachers (one of whom was female).

Located in the centre of Battambang Province, Upper secondary school 9 first opened as a lower secondary school in 1958 and then was upgraded to an upper secondary school in 1968.

This school was selected over the other big upper secondary schools in the province because of its proportion of students in the science and social science tracks. (At other schools, the majority of the students were in the social science track). In academic year 2017–2018 there were 2,025 students; and this number fell slightly to 1,969 in the last academic year, during which there were 202 (130 female) and 222 (172 female) grade 11th science and social science track, respectively. Of all 143 teachers (67 of whom were female), 35 were science teachers (12 of whom were female), and 13 mathematic teachers (though none of them were female). Most of them had many years of teaching experience and held a master's and/or a bachelor's degree at minimum.

In conclusion, there seems to be a good representation of upper secondary schools selected for the current study. There was a balance between schools in the urban areas, non-urban areas, regular schools, NGS, resource schools, and general and technical schools. Second, there were samples from schools that are concerned with the teacher shortage and the mismatch between the requirement for the job and schools with better qualified teachers.

4.5 Instrumentation

4.5.1 Students' questionnaire

A student self-rated questionnaire with 28 questions (25 closed-questions and 3 word-based questions) was employed to obtain information on grade 11th students, their families, and school related variables (see Appendix 2 for the questionnaire). Most of the questions were adapted from the other well-developed instruments. For example, the question on attitudes towards science was adapted from Kind, Jones, and Barmby (2007) in line with Fraser's (1981) Test of Related Attitudes (TORA) questionnaire, science and mathematics self-efficacy was adapted from the Pattern of Adaptive Leaning Scale (PALS)-ability to learn in science class (Fouad, Smith, & Enochs, 1997; Kao & Shimizu, 2019; Midgley et al., 2000), and interactive science and mathematics lessons was adapted from standards-based practices (Scantlebury, Boone, Butler Kahle, & Fraser, 2001). After developed and translated into Khmer language, the researcher requested two 11th graders to proofread the questionnaire and make any revisions to improve its readability and understandability. To improve reliability and content validity, piloting was also carried out to discern any mistakes or any misleading concepts, as well as problems with language use, answer choices, timing, procedures, and the like. The pilot was conducted with a total sample of 455 11th grade students (males=279, females=176) from seven upper secondary schools located in Phnom Penh and two provinces (Kampot and Kep) of Cambodia. The overall *Cronbach's* alpha of the questionnaire was α = .94, indicating high internal consistency. After piloting, some modifications were made to the questionnaire. For instance, a ten-item question on the general perception of tracking at upper secondary school was removed from the questionnaire as it had very low internal consistency. The measurement for the question on academic achievement was modified to make it consistent with the marking scheme of MoEYS. More importantly, the modification to the procedure for administering the survey through revision of instructions, was also made. Consequently, the final version of the questionnaire, which was used for collecting the data, was sectioned into two parts: background characteristics and subject information. The overall reliability of the questionnaire was α=.96 and the reliability by construct was α=.70 at minimum. Table 4.4 presents the variables included in the students' survey questionnaire.

Table 4.4: Detailed variables covered in the student questionnaire

Independent Variables of the 3 dimensions (21 variables) (8 time-invariant variables and 13 time-varying covariates)	**Dependent Variable**
• Individual dimension (1. Place of origin, 2. Gender, 3. Future plan in STEM, 4. Attitudes towards science, 5. Science self-efficacy, 6. Science and mathematics achievement, 7. Outcome expectations, 8. Hours spent self-studying) (These constructs were broken into time-invariant variables and time-varying covariates) • Family dimension (1. Parental education, 2. Parents in STEM, 3. Parental occupations, 4. Parental educational aspiration, 5. Family socio-economic status, 6. Relatives' occupations, 7. Relatives' major, 8. Parental support/encouragement) (These constructs were broken into time-invariant variables and time-varying covariates) • School dimension (1. School ID, 2. School location, 3. Tracking, 4. Support from science and mathematics teachers, 5. Interactive science and mathematics lessons) (These constructs were broken into time-invariant variables and time-varying covariates)	• STEM outcome (These indicators were measure by asking if the students are planning to major in STEM and by asking students to indicate their majors they are pursuing in higher education) (The majors indicated by the students was classified, based on list of majors [appendix 1], into STEM or Non-STEM majors.
Note: In general, independent variables were measured by multi-item psychometrics scales	

4.5.2 School checklist

To gather data on the characteristics of the sampled schools, a one-page school checklist was also developed. The aim of the school checklist was to collect information on the enrolment statistics regarding the two tracks of science and social science (NGS were included in the science track group), from academic year 2016–2018 to the latest date. Moreover, the statistics on the teachers at these respective upper secondary schools in general, and science and mathematics teachers in particular, were also included in the interview guide. In addition to the statistics, their qualifications as well as teaching experience and other factors that might influence their teaching practice were crucial. The background characteristics of the schools support the discussion of the findings in the main survey. In total, there were 15 questions (6 closed-ended and 9 open-ended questions) on the school checklist for interviewing the school management teams.

4.6 Variables and their measures

4.6.1 Dependent variables

The main dependent variable in this current study is the students' aspirations of STEM or non-STEM majors in higher education. Students' aspiration of STEM majors was coded as 1 and students' aspiration of non-STEM was coded as 0. This variable was measured by asking students to indicate the majors they intended or aimed to pursue in higher education after graduating from their upper secondary school education. Appendix 1 portrays a detailed classification of the academic majors in the two broad fields of STEM and non-STEM (the dependent variable in this study).

4.6.2 Independent variables

All independent covariates (variables) based on the three dimensions (individual, family, and school) were categorized into two different groups. The first group was named time-constant covariates. Those were the variables that did not change their value over time. For example, no matter how many times the data are gathered, the answer on gender of the samples remains the same. The second group was named as time-varying covariates. These were the variables that value were hypothesized to keep changing over time. The following section provides a full description of their meanings and measurements.

4.6.2.1 Time-constant covariates (TCCs)

4.6.2.1.1 Variables at the individual level

At this level, a number of individual-level demographic variables need further description in order to fully comprehend the meaning of the statistical values presented in the upcoming finding section. First, on dummy-coded *gender* variable, a male student was coded 0 while a female student was labeled 1. Second, *place of origin* was also a dummy-coded variable. The students originated from Phnom Penh was coded as 0 and the students who were from the other provinces rather than Phnom Penh was given a value of 1. With that said, the two provinces (Battambang and Kampong Cham) were dummy-coded into the other provinces in the SPSS dataset.

4.6.2.1.2 Variables at the family level

At the family level, three variables were categorized as time-constant covariates. First, *parental education level*, which was obtained from question #7.1 and #7.2 on the student' questionnaire (see Appendix 2), were measured on 1–6 ordinal scale. If a student's mother or father had not finished upper secondary school education, 1 would be coded on this variable. Parents who had completed upper secondary school were given a value of 2. Those who had completed an associate's degree were coded 3. Parents with a bachelor's degree, a master's degree, and a doctoral degree were labeled 4, 5, and 6, respectively. Second, the variable investigating if the students' parents with a bachelor's degree or above had majored in STEM (*parents' majors*) was obtained through dichotomous response questions #8.1 and #8.2. The participants indicated if their parents had majored in STEM by choosing 1 (if their parents majored in STEM) and indicated the major or choosing 0 (if they majored in non-STEM fields). Third, *parental occupation* was aimed to ask if their parents were working in STEM-related jobs. Students chose 1 and indicated the kinds of occupations their parents had if their parents were working in STEM related occupations. However, if their parents were working in non-STEM fields, students would mark 0.

4.6.2.1.3 Variables at the school level

There were three time-constant covariates at the school level. First, *school ID* was coded 1 to 9 for the upper secondary school 1 to upper secondary school 9 accordingly. This was used for schools comparison in the latter analysis. The second school-level variable was *school location*. On dummy-coded school location, the upper secondary school in Phnom Penh was coded 1 while the ones in the other two provinces were labeled 0. Third, in the same vein, *study track* of the students was also coded dichotomously. Code 1 was given to students who were taking science track in upper secondary school and coded 0 was labeled to those who were taking social science track.

4.6.2.2 Time-varying covariates (TVCs)

4.6.2.2.1 Variables at the individual level

Academic achievement deserves a thorough description. Because it is not the researcher's expertise, the researcher was unable to administer a standard test for all subjects in the upper secondary level to all sampled students. Rather, the norm-referenced academic achievement in general and the academic achievement (semester achievement and academic achievement) by subject (mathematics, physics, chemistry, biology, earth-environmental science, Khmer literature, history, geography, moral civics, and foreign language), in particular were used. The researcher thus used the annual academic achievement (the average score from semester 1 and semester 1). The score was later transformed to a standardized *z* score.

Future plan in science was a measure of five items on a five-point-Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). Factors analysis using a principle axis factoring with a Varimax and Kaiser normalization in rotation, produced only one factor (with an Eigenvalue of 2.61, a KMO statistics value of .78, and a Bartlett's test of sphericity significance value of less than .001). The variance explained was 52.19%. The Cronbach's alpha value for the five items of .83 indicated good internal consistency among the items. The factor loadings of the items ranged from .45 to .89.

Attitudes towards science was measured by six attitudes constructs, a modified version of attitudes towards science measure developed by Kind et al. (2007) (measured originally with 35 items): learning science in school (6 items), practical work in science (8 items), science outside of school (9 items), importance of science (5 items), and self-concept in science (7 items). Overall, the six constructs were measured on a five-point-Likert scale, with 1 denoting a negative response and 5 denoting a positive response (1 = strongly disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree, 5 = strongly agree). To ensure the relevance and internal validity of the measure within Cambodian context, exploratory factor analysis using principle axis factoring with Varimax and Kaiser normalization in rotation was employed. The analysis produced six distinct factors, and were named: science as a practical subject (measured by 7 items, having an Eigenvalue of 12.90), science and mathematics self-concept (measured by 6 items, having an Eigenvalue of 2.02), importance of science in society (measured by 5 items having an Eigenvalue of 1.80), interest in science at school (measured by 5 items, having an Eigenvalue of 1.11), science activities outside school (measured by 4 items, having an Eigenvalue of .98), and extracurricular activities in science (measured by 4 items, having an Eigenvalue of .69). The reliability of each variable was Cronbach's alpha = .76 the minimum. Table 4.5 presents the factor loadings. The KMO statistic of the attitudes towards science was .96. The Bartlett's test of sphericity significant value was less than .001, and the variance explained of the variable was 56.923%.

Table 4.5: Factor loadings of students' attitudes towards science

Variables	Items	Item descriptions	Factor Loadings
Science as a practical subject (Cronbach's alpha = .96)	7	▪ I like science practical work because I do not know what will happen.	.74
		▪ I would like more practical work in my science lessons.	.71
		▪ Practical work in science is good because I can work with my friends.	.70
		▪ Practical work in science is exciting.	.68
		▪ I like practical work in science because I can decide what to do myself.	.66
		▪ We learn science better when we do practical work.	.64
		▪ I look forward to doing science practical work.	.62
Science and mathematics self-concepts (Cronbach's	6	▪ Science is one of my best subjects.	.79
		▪ I learn science quickly.	.70
		▪ I get good mark in science.	.67
		▪ I am just good at science.	.67

alpha = .91)		▪ In my science class, I understand everything. ▪ I feel confident when doing science.	.65 .65
Importance of science in society (Cronbach's alpha = .82)	5	▪ Science and technology are helping the poor. ▪ Science and technology make our lives easier and more comfortable. ▪ The benefits of science are greater than harmful ▪ Science and technology are important for society. ▪ There are many exciting things happening in science and technology.	.70 .67 .64 .59 .56
Interest in science at school (Cronbach's alpha = .90)	5	▪ Science lessons are exciting. ▪ Science is interesting for me. ▪ I like science better than many other subjects at school. ▪ I would like to do more science at school. ▪ I look forward to my science lessons.	.59 .58 .54 .54 .43
Science activities outside school (Cronbach's alpha = .77)	4	▪ I like to visit science museum. ▪ I like watching science programme on TV. ▪ I like reading science magazine and books. ▪ It is exciting to learn about new things happening in science.	.69 .67 .51 .43
Extracurricular activities in science (Cronbach's alpha = .76)	4	▪ I have participated in science festival/STEM festival. ▪ I have participated in the event on STEM bus. ▪ I have participated in science and technology competition. ▪ I have participated in science and mathematics club.	.84 .74 .58 .49

Science and mathematics self-efficacy referred to how much students believed in themselves in doing science and mathematics subjects in upper secondary school (measured originally by 8 items on a five-point-Likert scale) (1 = strongly unconfident, 2 = unconfident, 3 = neither agree nor disagree, 4 = confident, 5 = strongly confident) loaded only one factor. The KMO statistics of science and mathematics self-efficacy measurement was .89. The variable had an

Eigenvalue of 4.32 and the Cronbach's alpha was .90 with the explained variance of 52.97%. The factor loadings of the items ranged from .62 to .81.

Science and mathematics outcome expectations referred to what will happen when students are performing well in science and mathematics in upper secondary school. The variable was measured originally by 7 items on a five-point-Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree, 5 = strongly agree). The items loaded only one factor with a KMO statistics of .90 and an Eigenvalue of 3.61. The Bartlett's test of sphericity significant value was less than .001. and the variance explained of the variable was 51.53%. The Cronbach's alpha value of .88 also indicated a good internal consistency among items and the factor loading of each item was .64 at minimum.

Hours spent self-studying at home was measured by one item asking students to indicate the numbers of hours they spent per week doing homework or self-studying for each of the following subjects: mathematics, physics, chemistry, biology, Khmer, history, geography, and other. The students completed the amount of certain number of hours, which then be used to calculate the mean hours spent self-studying science and social science subjects each week.

4.6.2.2.2 Variables at the family level

Parental educational aspiration referred to the highest educational level that the parents wanted their children (i.e., the students) to obtain. It was measured by one five-multiple choice item (1 = finished grade 12th, 2 = associate's degree, 3 = bachelor's degree, 4 = master's degree, 5 = doctoral degree).

Family socio-economic status was originally measured by three items: (1) monthly income of the family, (2) the number of family members who earn the income, and (3) the status of the parents (married or divorced). The first item asked the students to choose between four categories of income scale. If their family income was lower than 200 USD per month, code 1 was given. Code 2 was labeled to those who indicated that their family income was between 200 to 400 USD per month. If family monthly income was between 400 to 600 USD and more than 600 USD, coded 3 and 4 were labeled, respectively. The second item asked about who the main family income earner was. Code 1 was given to father, code 2 to mother and code 3 to both of them accordingly. The third item, with two categories response, was to investigate if the students lived in a two-parents or single-parent family. Code 1 was given to two-parents family and code 2 was labeled to the single-parent one.

Relatives' occupations and majors aimed to ask if any of the students' relatives were working in STEM fields. If their relative were working in STEM-related occupations, they chose 1 and indicated the occupations. If their relatives were working in non-STEM related fields, the students reported with code 0 and indicated the occupations.

Parental/social encouragement and support in science and mathematics (measured originally by 7 items on a five-point-Likert scale) also loaded only one factor. The Eigenvalue of the variable was 3.201, and the KMO statistics was .825. The Bartlett's test of sphericity significance value was less than .001. The variance explained was 45.722%. The variable also indicated a good internal consistency among the items as the Cronbach's alpha value was .85 and the factors loading score of each item was .58 at minimum.

4.6.2.2.3 Variables at the school level

Support from science and mathematics teachers referred to how science and mathematics teachers treat and guide their students during their teaching practice. It was measured originally by 12 items on a six-point-Likert scale (1 = never, 2 = almost never, 3 = some of the time, 4 = most of the time, 5 = almost always, 6 = always). The items loaded only one factor (since the factor loadings for 3 items were lower than the cut-off point of .40, only 9 items remained), having a Cronbach's alpha value of .89 and an Eigenvalue of 4.30). The KMO statistics of the variable was .90. The Bartlett's test of sphericity significance value was less than .001. The variance explained was 47.79%. The factor loadings of the items ranged from .57 to .76.

Interactive science and mathematics lessons (measured originally using 7 items), and which reflects how science and mathematics lessons are regularly conducted also loaded only one factor. The Eigenvalue of the variable was 2.33, the KMO statistics was .84, and the Bartlett's test of sphericity significance value was less than .001. However, the variance explained was only 33.25%. The Cronbach's alpha value of .775 also indicated a good internal consistency among the items. The value of factor loading of the items was .49 at minimum and .64 at maximum. Table 4.6 summarizes the variables, data type, and range of responses.

Table 4.6: List of all variables discussed, specific items on the questionnaire, data type, and range of responses

Variables	Measures/Instruments	Data type	Range
Individual Factor			
Gender	Questionnaire Q1	Nominal	1-2
Place of origin	Questionnaire Q2	Nominal	1-2
Hours spent self-studying	Questionnaire Q16	Scale	--
Science and mathematics self-efficacy	Questionnaire Q14, Q20	Scale	1-5
Science and mathematics achievement	Questionnaire Q15	Scale	1-5
Outcome expectation	Questionnaire Q22	Scale	1-5
Science as a practical subject	Questionnaire Q21	Scale	1-5
Science and mathematics self-concept	Questionnaire Q21	Scale	1-5
Importance of science in society	Questionnaire Q21	Scale	1-5
Interest in science at school	Questionnaire Q21	Scale	1-5
Science activities outside school	Questionnaire Q21	Scale	1-5
Extracurricular activities in science	Questionnaire Q21	Scale	1-5
Future plan in science	Questionnaire Q19	Scale	1-2
Plan to major in STEM	Questionnaire Q17-Q18	Nominal	1-2
Family Factor			
Father's education	Questionnaire Q7	Ordinal	1-6
Mother's education	Questionnaire Q7	Ordinal	1-6
Father majored in STEM	Questionnaire Q8	Nominal	1-2
Mother majored in STEM	Questionnaire Q8	Nominal	1-2
Father in STEM occupation	Questionnaire Q9	Nominal	1-2
Mother in STEM occupation	Questionnaire Q9	Nominal	1-2
Relatives in STEM occupation	Questionnaire Q10	Nominal	1-2
Parental educational aspiration	Questionnaire Q5	Ordinal	1-5
Family socio-economic status	Questionnaire Q11-Q13	Ordinal	1-4
Family encouragement and support	Questionnaire Q25	Scale	1-5
School Factor			
School ID	Questionnaire Code	Nominal	1-9
Tracking	Questionnaire Q3, Q6	Nominal	1-2

Science and math teachers' support	Questionnaire Q23	Scale	1-6
Interactive science and math lessons	Questionnaire Q24	Scale	1-4
Dummy school location	Questionnaire Code	Nominal	1-2
Three open-ended Questions	Questionnaire Q26-Q28	Word-based	

4.7 Observation period and interval

Since this repeated cross-sectional study was in panel design, first researcher collected data, and after a certain period of time, the data was collected again. Due to personal reasons and high cost of travelling and time required, the researcher was able to check on the progress of the students and the sampled schools only two times—at the beginning of grade 11th and at the end of grade 11th. Put simply, the researcher checked the progress of the students and the sampled schools after the students have studied six months from the beginning of the academic year. Thus, it should be clarified that the observation interval for this study was 6 months (about one academic year period).

The first wave of fieldwork was conducted on 23rd November 2018; this period lasted for one and half months. According to the new Cambodian school calendar, all schools open in early November. However, because students may rotate from one class to another (from *A to B to C, etc.*) in the first few weeks, the researcher began the first wave of fieldwork at the end of November. This allowed some time for the students to decide the actual class they might be placed in, and for researcher to have administrative documents and other logistics arranged. During the data collection period, questionnaires were distributed to early 11th graders and obtained their academic scores (by subject) from grade 10th.

At the end of the academic year, the second wave of fieldwork was undertaken from 22nd July 2019 to 11th August 2019. There were several more supplementary tasks than the first wave; mainly the researcher needed to identify who had changed from the science track to the social science track at upper secondary school and vice-versa. Also, information on the schools, such as the number of students, teachers' qualifications, and teaching experience were collected. The researcher administered the same set of questionnaire to the same students. This second observation was to examine the trends and patterns of changes in time-varying covariates resulting from attending in different tracks across one academic year span.

4.8 Data collection procedure

Conducting a repeated cross-sectional study in general, and a panel design in particular, was one of the most challenging tasks, especially in terms of data collection. This section therefore details how the data of this study was collected. First, after receiving the permission letter from the authorizing department, Department of Higher Education, the researcher sent the letters to the targeted upper secondary schools so as to seek their approval. The researcher made an appointment as soon as the request was approved. At upper secondary school, there were three main steps undertook to collect the data.

First, the researcher asked for a list of all grade 11th in that particular school. Stratified random sampling was then employed to select one or two classes each from the science track and the social science track, respectively. As the classes were identified, the researcher had to go to that randomly selected classes to begin the data collection procedure. Prior to administering the questionnaire, researcher explained to the students the objective, purpose, contribution, and how to complete the questionnaire (specifically each part). The students needed approximately 45 to 60 minutes to fill out the questionnaire.

As the in-class collection procedure finished, the third step was to collect data on academic achievement of each participating students. The researcher worked with the school principal or vice-principal in charge to obtain the students' academic scores of grade 10th and grade 11th. The academic achievement was recorded from the so-called *Academic record booklet*. The academic scores of the 10 subjects (mathematics, physics, chemistry, biology, earth-environmental science, Khmer literature, history, geography, moral civics, and foreign languages) were recorded for each sample. Although researcher asked about these scores in the questionnaire, students may have forgotten their scores or gave incorrect ones. Researcher applied this process (except for the first step) in the second phase of data collection.

4.9 Data analysis

4.9.1 Data processing

Prior to the main data analysis several steps of data processing to manage the current study's data were employed. First, after the collection of the survey questionnaire, the researcher checked the data manually to see if the questionnaires had been completely filled out and if the inform consent form had been properly signed. The questionnaires missing any information or left the consent form unsigned were withdrawn from the study. Coding were made on the personal information slip as well as on the questionnaire. Second, the researcher entered all personal information of the respondents and the codes of the questionnaire into the data spreadsheet. The information slip was then removed from the questionnaire. Next, researcher started to enter data into the basic spreadsheet database of Microsoft Excel. After the data entry was completed, the researcher conducted some preliminary checks on the data with some descriptive statistics such as frequency, mean, and range to check for errors in data input and the missing values. After the data had been cleaned, the researcher imported the data into the specialized Statistical Package for Social Sciences (SPSS) version 23 for Macintosh. The researcher also conducted further exploratory data analysis and some other descriptive statistics including frequency, mean, standard deviation, skewness, kurtosis, exploratory factor analysis, reliability analysis, and other basic statistical assumptions testing. All in all, the main purpose of the data processing was to have a clean and complete dataset ready for the main data analysis process.

4.9.2 Overall data analysis

Table 4.7 illustrates the overall analytical method and the expected forms of results for each research question.

Table 4.7: Research methods by specific research objectives

Research Questions	Specific objectives	Specific research questions	Analytic methods	Expected forms of results to be presented
Research Question 1 (Finding I)	Factors influencing science track choice	What are the effects of individual, family, and school on students' choice of science track in upper secondary school?	Binary logistics regression Thematic Analysis	Table of statistical difference and significance on the factors explaining the science track
Research Question 2 (Finding II)	Trends of time-varying covariates	What are the trends of time-varying covariates?	Descriptive statistics (i.e. frequency, percentage, mean score, and graphic display)	Frequency, percentage, graph, cross-tabulation and effect size

	Patterns of time-varying covariates across three demographic variables as well as observation	Are the patterns of time-varying covariates differentiated by demographic attributes (gender, school location, study track) across one academic year?	Independent sample t-test, Pair sample t-test, ANCOVA, Repeated ANOVA	Table of statistical difference and significance and effect size
Research Question 3 (Finding III)	Effects of tracking on aspiration of STEM majors	What are the effects of the tracking system on students' aspirations of STEM majors?	Bernoulli Hierarchical Linear Modeling (HLM) Thematic Analysis	Percentage of variation on class different, table of statistical significance of the association between science track and aspiration of STEM majors.
	Effects of individual, family, and school variables on aspiration of STEM majors	What are the effects of individual, family, and school variables on students' aspirations of STEM majors?		Table of statistical significance predictors on STEM majors

4.10 Qualitative design and methods

4.10.1 Samples and sampling

Because this current study was an explanatory sequential mixed method approaches, the participants recruited for the qualitative interview were selected based on the results of the first (quantitative) phase. In order to choose specific students who had experienced and could provide information related to the study, stratified purposive random sampling were employed. The participants selected for the interviews were stratified from three different categories: (1) students who had changed from the science track to the social science track, (2) science track students who aspired to pursue a non-STEM majors, and (3) science track students who aspired to pursue STEM majors in higher education. Based on this purpose, the researcher randomly selected 14 students for the first category, 22 students for the second category, and 17 students for the third category. However, because some students could not be reached through social media (Facebook messenger, Zoom, Telegram, or others) to conduct the online interviews, and as some students did not agree to participate in online interviews, there were only 4, 9, and 12 students for the first, second, and the third categories selected, respectively. See Table 4.8 for the interviewees' demographic information.

Table 4.8: Demographic information of the interviewees

Variable and attribute		Frequency	Percentage
Gender	Male	9	36%
	Female	16	64%
School Type	Traditional	16	64%
	New Generation	9	36%
Location	Phnom Penh	9	36%
	Province	16	64%
Category	Science to social science	4	16%
	Science to non-STEM	9	36%
	Science to STEM	12	48%
Approach	Individual Interview	15	60%
	Focus group interview	10	40%

4.10.2 Qualitative interview instrument

The researcher also developed a specific semi-structure interview protocol to clarify the underlying explanations of the factors that influenced students' choice of the science track at upper secondary school *(RQ1)* and their relationship with the students' aspirations of STEM majors in higher education *(RQ3)* revealed through the quantitative investigation. Creswell (2014) emphasized that the types of qualitative questions to ask participants in the second phase are informed by the quantitative results of the first phase. Therefore, the questions included in the interview protocol were guided by the results of the quantitative survey. (See Appendix 5 for the semi-structured interview protocol.) The core parts of the protocol consisted of students' future plan in science, their achievement and experiences in science classroom, their relationships with their families, and their relationships with their science and mathematics teachers (who may have played a role in students' aspirations of STEM majors). Also, the protocol was aimed to understand the students' feelings towards science both inside and outside the classroom, their perceptions of the factors that influence them to leave or to stay in science, and how to improve their aspirations of science track and STEM majors.

4.10.3 Qualitative data collection

The interviews and focus group interviews took place throughout July 2020. The interviews were conducted online in Khmer language (via Facebook messenger, Telegram, and/or

ZOOM). The interviews lasted from 30 minutes to 1 hour depending on the quality of Internet connection, the availability of the participants, and their willingness to express more insights. The researcher first needed to arrange the interviews with the students, since they also have had to take online classes during the Covid-19 pandemic. The interviews were mostly conducted in the evening and on the weekend. Since the researcher did not want to miss the exact words from the interviewees and to increase the transferability of the data, the researcher requested permission to record the interviews, which all students granted.

4.10.4 Qualitative data analysis and interpretation

According to Creswell (2014), the quantitative and qualitative data in explanatory sequential mixed method approaches should be analyzed separately. Therefore, the analysis of the qualitative data in this current study was made after finishing the interviews. Overall, the analysis followed the approach of qualitative data analysis of coding and thematic analysis. The following were the data analysis and representation steps (Williamson, Given, & Scifleet, 2018):

- Step1: *Data organization:* the interviews were transcribed and translated into English. The researcher organized the data according to the categories of the respondents.
- Step 2: *Reading and memoing:* research first read through all the transcripts from all the respondents to get a holistic understanding of the data and made some memos on the margins of the script.
- Step 3: *Describing the data into codes and themes (open coding):* researcher read five transcripts and made margin notes.
- Step 4: *Classifying the data into codes and themes (axial coding):* researcher re-read the transcripts and began to develop a set of categories that worked across them. The categories were listed and used as coding manual for analyzing the other transcripts.
- Step 5: *Using open coding and axial coding to code other data:* the remaining transcripts were coded using the codes in the manual, but the list could be added and refined.
- Step 6: *Coding towards themes or categories (selective coding):* the categories and sub-categories were listed. The major themes should now be drawn from the list.

Briefly explain, to analyze the data from the individual interviews and focus group interviews, first the researcher transcribed the data. Since the interviews were conducted in Khmer language, the transcripts were made in Khmer language. As the transcript was done, the researcher organized the data according to the categories of the respondents (science to social science, science to STEM, and science to non-STEM majors). Second, research first read through all the transcripts to gain a holistic understanding of the data and wrote down some memos in the margins of the scripts. Next, the researcher began to critically read five transcripts and made the margin notes of the codes. Fourth, the researcher re-read the transcripts and began to develop a set of categories that worked across them. During this axial coding, categories were connected to identify themes (Strauss & Corbin, 1999) by summarising the highlighted codes and categories for each participant in order to develop themes and patterns among individuals. The categories were listed and used as coding manual for analyzing the other transcripts. Next, to code the remaining transcripts, the research used the coding manual developed. However, the list of the codes was able to be refined as there was any emerging codes. Finally, the categories and sub-categories were listed so as to draw emerging themes that corresponded to the guided questions. The researcher recorded the themes in Microsoft Excel spreadsheet.

In the explanatory sequential mixed method approaches, researcher interpreted the follow-up qualitative findings in a *discussion section* of the study. Creswell and Creswell (2018) directed that researcher should first report on the results of the first (quantitative) phase and then the findings of the second (qualitative) phase. The qualitative findings were used to provide insight into the quantitative findings. Therefore, in this study, the qualitative findings were interpreted and discussed in *each quantitative finding* and in the *overall discussion* respectively.

Grounded in the specific research objectives and variables, Figure 4.5 further illustrates the holistic analytical framework for the current study. It indicates the time-invariant variables and time-varying covariates within the three dimensions of individual, family, and upper secondary school. The figure further indicates which variables and how the current study analyzed the data for each specific research question. Again, the main outcome for the first wave of data relates to explaining upper secondary school students' choice of the science track *(Research Question 1)*. The outcomes of the first and the second waves of data were the trends and patterns of time-varying covariates across the two observations (as a function of gender, school location, and study track *[Research Question 2])*. The outcomes of the second wave of data entailed investigating the effects of tracking and other multi-dimensional variables on Cambodian upper secondary school students' aspirations of STEM majors from a multilevel analysis perspective *(the main research question, Research Question 3)*.

4.11 Analytical framework of the current study

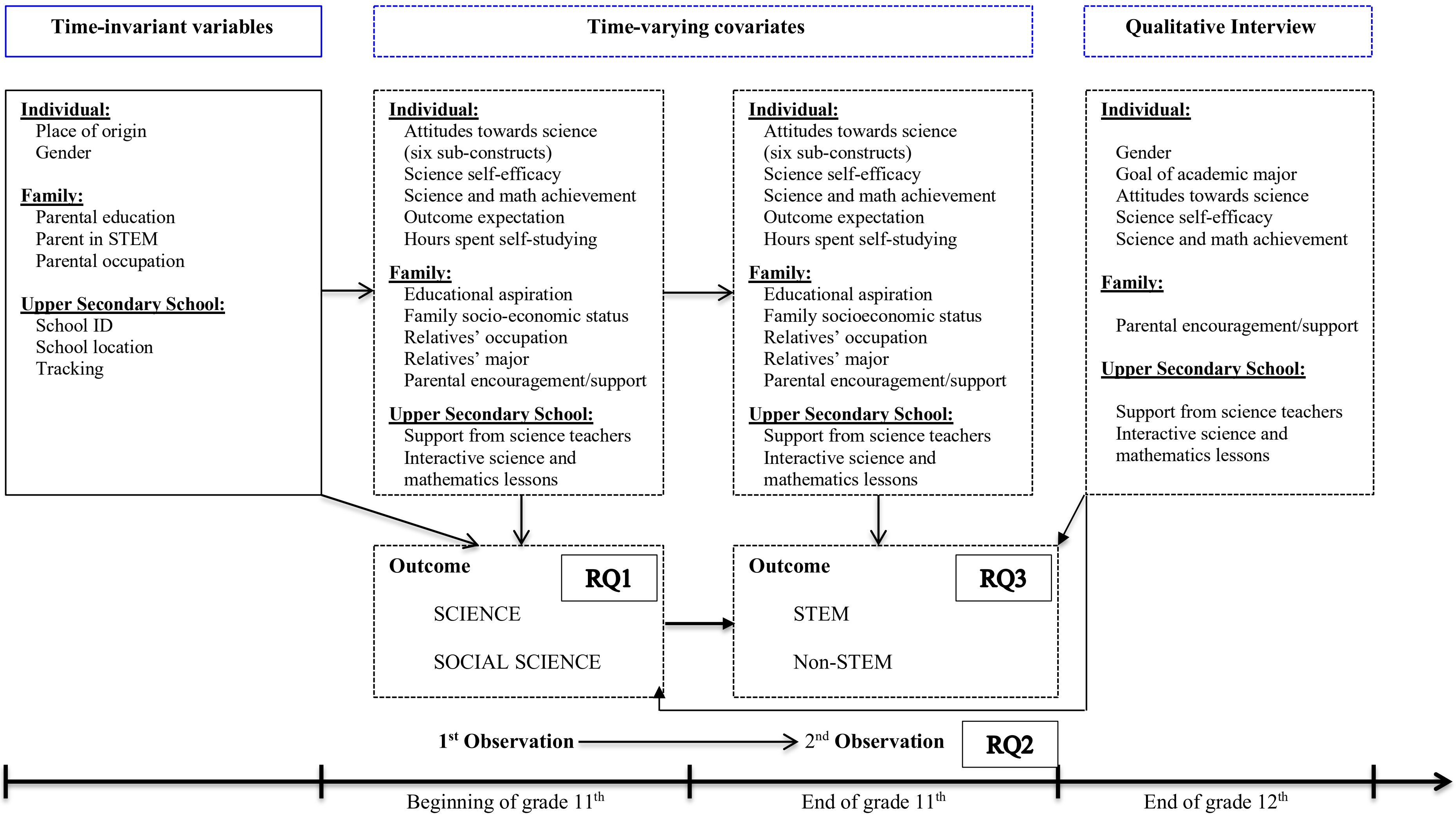


Figure 4.5: Model specification for the analytical framework of the study

CHAPTER FIVE: CHOICE OF THE SCIENCE TRACK: FINDING I

The problem, objective, the framework, and the *"how"* components of the current study discussed in the previous chapters serve as the foundation for displaying the purpose of this chapter. This chapter, therefore, starts with the details of the first key finding of the study. Put simply, the chapter displays and discusses the findings on factors that explained Cambodian upper secondary school students' choice of the science track. Employing the main conceptual framework, the current study looked at the factors from the three dimensions stated earlier (individual, family, and upper secondary school related factors). This chapter begins with the method (samples and data analysis) and ends with a discussion and conclusion responding to research question 1.

In this chapter, the researcher addressed the following research question as follow.

RQ 1: What factors (individual, family, and school) are influencing Cambodian upper secondary school students' choice of science track?

5.1 Method for RQ 1

5.1.1 Samples

As briefly reported, the data from the first wave was analyzed to answer research question 1. Therefore, the data for the first research question was collected from 752 early grade 11th students from 9 upper secondary schools in the three provinces (Phnom Penh, Kampong Cham, and Battambang) of Cambodia. Of these samples, 44% were male students and 56% were female students. In this first wave data, from the tracking perspective, 61.8% of the students were in the science track and 38.3% were in the social science track. While 47.1% were from urban areas, 52.9% were from non-urban areas.

5.1.2 Data analysis method

It is worth to remind here that the first objective of this current study was to investigate the factors that explained Cambodian upper secondary school students' choice of the science track versus the social science track. Since the outcome variable was coded dichotomously, *Binary Logistic Regression* (Field, 2009; Leech, Barrett, & Morgan, 2005), *Enter Method*, was employed to estimate the effects of the independent variables on the likelihood of the Cambodian students' choice of the science track at upper secondary school. To address the issue, block recursive model, that makes explicit assumptions about the causal order of individual, family, and upper secondary school level variables was employed. Specifically, as illustrated in Table 5.1, the independent variables were entered into three "blocks":

Table 5.1: Methods of estimation for Finding I

Model	Block of independent variables included in the regression model
1	I (Individual Factor)
2	I (Individual Factor) + II (Family Factor)
3	I (Individual Factor) + II (Family Factor) + III (Upper secondary school Factor)

By using a block recursive model, the total effects of individual-level predictors on students' choice of the science track (*Model 1*), as well as the net effects of individual-level factors as mediated by family-level predictors (*Model 2*), and the effects of upper secondary school-level predictors (*Model 3*) could be determined.

Additionally, prior to the main analysis, since the data contained a large scale of items in which multi-collinearity can cause great concern, data reduction was also taken into account. For this reason, as well as to identify the constructs underlying the group of the survey items, exploratory factor analysis using principal axis factoring with Varimax and Kaiser normalization in rotation was performed on the items. The measurement section of the study discusses the factors identified from this exploratory factor analysis.

Moreover, although the main analytical tool for research question 1 was *Logistic Regression*, some other analytical tests (including chi-square, independent sample t-test, and linear and multiple regression) were used to find out the relationships among all variables, and to check whether or not the third variables played any influential role in explaining students' choice of the science track. Moreover, categorical predictors such as father's and mother's occupations and majors were recoded into dummy variables before entering them into the logistic regression model. Statistically, to avoid *multi-collinearity*, collinearity statistics analysis in multiple regression was also conducted, which revealed that no variable had a *Tolerance* *statistics* value of lower than .05 or a variance inflation factor (*VIF)* value higher than 7 (Field, 2007). Therefore, there was no issue of multi-collinearity presented.

For the last stage of data analysis for research question 1, which was intended to detect the root influential factors predicting Cambodian upper secondary school students' choice of the science track, the study employed logistic regression. Table 5.2 illustrates the list of variables included in the Binary Logistic Regression analysis by each block of individual-level, family-level, and upper secondary school-level factors. Simply mention, the method of analysis took into account the framework of the present study as well as the variation from one model to another. By and large, the whole process of data analysis for research question 1 employed advanced version of Statistical Package for the Social Science (SPSS) software (version 23 for Macintosh).

Table 5.2: Variables included in the logistic regression model

Variables	**Definition/code**
Dependent	
Choice of Track	0=social science track, 1=science track
Independent	
Individual Level Factors	
Gender	0=female, 1=male
Hours spent self-studying mathematics	Average number of hours per week
Hours spent self-studying physic	Average number of hours per week
Hours spent self-studying chemistry	Average number of hours per week
Hours spent self-studying Khmer	Average number of hours per week
Performance in science subjects	1=poor/fail, 2=average, 3=fair good, 4=good, 5=very good, 6=excellent
Performance in social science subjects	1=poor/fail, 2=average, 3=fair good, 4=good, 5=very good, 6=excellent
Science and math outcome expectations	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Science and math self-efficacy	1=strongly unconfident, 2=unconfident, 3=neutral, 4=confident, 5=strongly confident
Science as a practical subject	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Science and math self-concept	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

Importance of science in society	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Interest in science at school	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Science activities outside school	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Future plan in science	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Plan to major in STEM	0=No, 1=Yes
Family Level Factors	
Father's education	1=did not finish high school; 2=completed high school, 3=completed an associate's degree, 4=completed a bachelor's degree, 5=completed a master's degree; 6=completed a doctoral degree
Mother's education	1=did not finish high school; 2=completed high school, 3=completed an associate's degree, 4=completed a bachelor's degree, 5=completed a master's degree; 6=completed a doctoral degree
Father majored in STEM	0=No, 1=Yes
Mother majored in STEM	0=No, 1=Yes
Father in STEM occupation	0=No, 1=Yes
Mother in STEM occupation	0=No, 1=Yes
Relatives in STEM majors	0=No, 1=Yes
Family income	1=lower than 200$, 2=200$-300$, 3=400$-500$, 4=more than 600$
Family encouragement and support	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
School Level Factors	
Science and math teachers' support	1=Never, 2=almost never, 3=some of the time, 4=most of the time, 5=almost always, 6=Always
Interactive science and math lessons	1=almost never, 2=sometimes, 3=often, 4=very often
Dummy school location	0=province, 1=Phnom Penh

5.2 Results of RQ 1

5.2.1 Descriptive results

Table 5.3 illustrates the descriptive statistics (the *mean [M], standard deviation [SD], and minimum and maximum*) of the three-dimension variables included in the Binary Logistic Regression. The descriptive statistics reveal some basic findings related to individual students and the characteristics of the other dimension variables. First, the dependent variable of the current study was the choice of track (science versus social science). Among the total sample of 752 students, 61.8% were in the science and 38.3% were in the social science track. There seemed to be an imbalance of students between the two tracks because science classes were only offered at two selected NGS in Phnom Penh and Kampong Cham Provinces.

Table 5.3: Descriptive results of the variables included in the logistic regression model

Variables	Mean	SD	Minimum	Maximum
Dependent				
Tracking	-	-	0	1
Independent				
Individual Level Factors				
Gender	-	-	0	1
Hours spent self-studying mathematics	3.45	2.96	0	24
Hours spent self-studying physics	2.55	2.32	0	21
Hours spent self-studying chemistry	2.40	2.11	0	21
Hours spent self-studying Khmer	2.86	2.50	0	21
Performance in science subjects	2.33	.81	1	5
Performance in social science subjects	2.99	.75	1	5
Science and math outcome expectation	3.83	.65	1	5
Science and math self-efficacy	2.97	.69	1	5
Science as a practical subject	3.53	.78	1	5
Science and math self-concept	2.76	.72	1	5
Importance of science in society	3.79	.64	1	5
Interest in science at school	3.32	.78	1	5
Science activities outside school	3.46	.69	1	5
Future plan in science	3.30	1.03	1	5
Plan to major in STEM	-	-	0	1
Family Level Factors				
Father's education	1.94	1.39	1	6
Mother's education	1.59	1.07	1	6
Father majored in STEM	-	-	0	1
Mother majored in STEM	-	-	0	1
Father in STEM occupation	-	-	0	1
Mother in STEM occupation	-	-	0	1
Relatives in STEM major	-	-	0	1
Family income	2.11	1.07	1	4
Family encouragement and support	3.36	.67	1	5
School Level Factors				
Science and math teachers' support	4.14	.88	1.60	6
Interactive science and math lessons	2.84	.51	1	4
Dummy school location	-	-	0	1

Of the independent variables, since gender was measured dichotomously, mean score calculation was not applicable. However, based on the descriptive statistics, 56% of the sample was female and 44% was male. Next, hours spent self-studying mathematics and science subjects entailed the average number of hours per week each student spent self-studying at home. On average, students spent several hours (*M*=3.45, *SD*=2.96) on mathematics, (*M*=2.55, *SD*=2.32) physics, (*M*=2.40, *SD*=2.11) chemistry, and (*M*=2.86, *SD*=2.50) Khmer literature. With regards to academic performance, based on MoEYS grading guidelines, most students had lower performance in science and mathematics subjects (*M*=2.33, *SD*=.81) than social science subjects (*M*=2.99, *SD*=.75). With this performance being just above average, although students seemed to have a higher level of science and mathematics outcome expectations (*M*=3.83, *SD*=.65), they tended to have a moderate level of science and mathematics self-efficacy (*M*=2.97, *SD*=.69). Most of note, for attitudes towards science sub-constructs, the students had higher views of the practicality of science subjects (*M*=3.53, *SD*=.78), lower science and mathematics self-concepts (*M*=2.76, *SD*=.72), higher attitudes towards the importance of science in society (*M*=3.79, *SD*=.64), higher attitudes towards science at school (*M*=3.32, *SD*=.78), higher attitudes towards science activities outside school (*M*=3.46, *SD*=0.69), and future plan in science (*M*=3.30, *SD*=1.03). Interestingly, 57% of the students planned to major in STEM, while 43% did not have any plan.

In terms of family-level factors, most of the students' fathers had finished upper secondary school (*M*=1.95, *SD*=1.39), but their mothers had an even lower level of education (*M*=1.59, *SD*=1.07). Also, a lower percentage of them majored in STEM, and even fewer worked in STEM-related occupations (less than 10%). Another predictor of family factors, the family's monthly income, seemed to fall somewhere between 200–400 USD (*M*=2.11, *SD*=1.07). Lastly, reflected in Cambodia's supportive culture, students received a high level of encouragement and support from their families (*M*=3.36, *SD*=.67) in choosing to study science.

Last, for upper secondary school-level factors, the students also seemed to receive moderate support from their science and mathematics teachers regarding their choice of the science track (*M*=4.14, *SD*=.88). However, the teaching of science and mathematics lessons were not very interactive (*M*=2.84, *SD*=0.51). Lastly, based on a dummy-coded variable, 52.9% of the samples attended upper secondary schools in the provinces, while only 47.1% were from schools in Phnom Penh.

5.2.2 Interpretation and overall fit of the model

To gain deeper insight into the factors affecting students' choice of the science track, analysis by model (the individual-level factor model, the family-level factor model, and the upper secondary school-level factor model) was conducted. *Binary Logistic Regression, Enter Method* was employed because the dependent variable was dichotomously coded (0 for social science track and 1 for the science track). In this regard, to facilitate the statistical interpretation of the logistic regression results, three mechanisms for data reading were utilised. First, to see if the model was a significant fit for the data, the *-2log-likelihood* statistic and its associated *chi-square statistics* should be examined. This could be obtained from the analogue of *Cox & Snell R square* or *Nagelkerke R square*. In statistical terms, the proportion presented the amount of variance in the students' choice of the science track, accounted for by a combination of variables under each main factor (such as individual, family, and upper secondary school factors). However, the interpretation in this study was based on the *Cox & Snell R square* as it was more accurate than its counterpart. While the value of the *Cox and Snell R Square* ranges from 0–.75, the value of *Nagelkerke R square* ranges from 0–1. Second, to see the relationship of each variable contributing to explain the variance in the students' choice of the science track, researcher examined the value of *coefficient (B)*. The interpretation was based on the direction of the sign and numeric value. For instance, in an equation where the science track is the referenced category, a negative coefficient indicates that individuals with a higher value for the independent variables are more likely to choose the social science than the science track and vice versa. Third, the coefficient or odds ratio *Exp(B)*, when exponentiated and subtracted from 1, was interpreted as an indicator of the change in odds resulting from a unit of change in the predictor variables. Put simply, it explains the level of change in the likelihood of the students' choice of the science track derived from a unit of change of each significant predictor variable. For ease of interpretation, the formula *[Exp(coefficient)–1]* x *100* was used to convert the coefficient into percentage differences in terms of odds.

Before delving into the explanation of each significant variable, let's have a look at the snapshot of the overall fit of the data to the model. Logistic regression analysis exhibited that the total factors related to Cambodian upper secondary school students' choice of the science track explained 48.7% of the variance in students' choice (Cox & Snell R Square=.487; see Table 5.4). To be specific, individual-level factors accounted for 46.9% (Cox & Snell R

Square=.469) of the variance explaining Cambodian upper secondary school students' choice of the science track. The inclusion of family background and encouragement as well as upper secondary school experience and support factors in the second and third regression models, increased the value to 48.3% (Cox & Snell R Square =.483) and 48.7% (Cox & Snell R Square=.487) of the variance predicting students' choice of the science track, respectively. The *-2log-likelihood* ratio of the model was significant, with *chi-square statistics* of less than .05 (*p* =.000). Most of note, the chi-square value of the *Hosmer and Lemeshow test* was larger than .05 (*p* >.05), meaning that there was no misspecification in the model. Statistically speaking, as a reflection of the results, it could be concluded that the model significantly fit the data well. From the theoretical perspective, the results of the model testing imply that the data support the applicability of the conceptual models, which was used as the conceptual framework of the current study.

Table 5.4: Estimation results for upper secondary school students' choice of the science track

Significant Predictors	***Model 1***		***Model 2***		***Model 3***	
	B(SE)	***Exp(B)***	**B(SE)**	***Exp(B)***	**B(SE)**	***Exp(B)***
Hours spent self-studying mathematics	.29(.23)**	1.34	.28(.11)**	1.32	.29(.108)**	1.33
Hours spent self-studying chemistry	.42(.16)**	1.52	.48(.16)**	1.62	.47(.163)**	1.61
Hours spent self-studying Khmer	-.41(.08)***	.66	-.38(.09)***	.68	-.36(.087)***	.70
Performance in science subjects	1.15(.22)***	3.16	1.04(.24)***	2.83	1.03(.238)***	2.81
Performance in social science subjects	-.55(.18)**	.57	-.66(.19)**	.52	-.60(.195)**	.55
Science as a practical subject	.88(.25)***	2.42	.75(.26)**	2.12	.73(.264)**	2.07
Interest in science at school	.67(.24)**	1.96	.71(.25)**	2.03	.72(.251)**	2.05
Future plan in science	.32(.16)*	1.38	.29(.17)	1.35	.29(.171)	1.33
Plan to major in STEM	.88(.25)***	2.40	.97(.27)***	2.63	1.04(.274)***	2.82
Mother's education			.40(.18)**	1.65	.43(.184)*	1.54
Family encouragement and support			.44(23)	1.56	.48(.231)*	1.61
School location (other provinces)					.66(.268)*	1.93
Cox & Snell R Square	.469		.483		.487	
Nagelkerke R Square	.638		.656		.662	

Note: * when p < .05; ** when p < .01; *** when p < .001

Second, Table 5.4 summarizes the influence of individual, family, and upper secondary school-level factors on Cambodian upper secondary school students' choice of track. As it indicates, when the other main factors were not counted, the first model (for individual-level factors) showed the estimate of significant variables counting from hours spent self-studying chemistry and mathematics, performance in science subjects, science as a practical subject, interest in science at school, future plan in science, and plan to major in STEM. Of these, the total variance explained of students' choice of the science track was 46.9% (Cox & Snell R square=.469).

Interestingly, the inclusion of the second model (for family-level factors) into the first model—in which the mother's education level had a significant influence—expanded the total variance. Of the total variance explained by the first model (46.9%), family-level factors increased the variance to 48.3% (an increase of about 1.4%). However, the inclusion of this model had neutralized the effect of future plan in science in the first model, because the coefficient value of the future plan in science was a bit low, at .32 ($p < .05$). Lastly, regarding the inclusion of the third model (for upper secondary school factors), and the total variance explained by the entire model (48.7%), the third model added 04% to the variance in students' choice of the science track.

5.2.3 Factors influencing upper secondary school students' choice of the science track

5.2.3.1 Individual-level factors

The outcomes of logistic regression analysis indicate that individual-level factors impact Cambodian upper secondary school students' choice of the science track. Overall, the model explained 46.9% (Cox & Snell R Square =.469) of the variance explaining students' choice of track (see Table 5.5). Among the key factors that survived in the model, the variables included students' background characteristics, personal ability, and attitudes or behaviours accordingly. In particular, the following significantly predicted Cambodian upper secondary school students' choice of the science track: performance in science subjects (Exp(B)=3.16), science as a practical subject (Exp(B)=2.42), plan to major in STEM in higher education (Exp(B)=2.40), interest in science at school (Exp(B)=1.96), hours spent self-studying chemistry (Exp(B)=1.52), and hours spent self-studying mathematics (Exp(B)=1.34).

Regarding influential factors, students with higher *performance in science subjects* were more likely to choose the science track at the rate of 3.16 times higher than those with poor performance in science subjects (Exp(B)=3.16, $p < 0.001$). Conversely, students with higher performance in social science subjects were less likely to choose the science track

(Exp(B)=0.57, p <0.01). The expected value of science performance was found to be statistically significant, with variation from 2.06 to 4.86.

The qualitative data confirmed that, in terms of performance in science subjects, all respondents considered their science performance when deciding which track to choose. Students (84%) who chose the science track explained that they did so because of their strong background in science. The interview respondents stated:

> First, I wanted to choose the [social science] track, but I switched to science because at the time, the school required me to choose one specialized class and I was interested in physics. When I was in grade 10^{th} I tried and was good at physics. My teachers also said that I was good at physics, so I chose science track.

In contrast, students who chose the social science track explained that they did so because they were not good at science and mathematics but were good at Khmer literature. One student remarked: "Since I was young, I think that I have liked Khmer literature. I can understand letters [Khmer] much quicker than numbers [mathematics]…I am sure that I could not do with this [mathematics] subject". Therefore, the qualitative results underscore that science and mathematics achievement matter regarding the likelihood of Cambodian students' choosing the science track.

Table 5.5: Individual-level factors predicting students' choice of the science track

Model 1: Individual Level Factors	B(SE)	95.0% C.I. for EXP(B)		
		Lower	Exp(B)	Upper
Constant	-6.53(1.09)***		.00	
Hours spent self-studying mathematics	.29(.23)**	1.10	1.34	1.65
Hours spent self-studying chemistry	.42(.16)**	1.12	1.52	2.06
Hours spent self-studying Khmer	-.41(.08)***	0.56	0.66	0.78
Performance in science subjects	1.15(.22)***	2.06	3.16	4.86
Performance in social science subjects	-.55(.18)**	0.40	0.57	0.82
Science as a practical subject	.88(.25)***	1.49	2.42	3.92
Interest in science at school	.67(.24)**	1.22	1.96	3.15
Future plan in science	.32(.16)*	1.01	1.38	1.89
Plan to major in STEM	.88(.25)***	1.47	2.40	3.92
Cox & Snell R Square	.469			
Nagelkerke R Square	.638			

Note: * when p < .05; ** when p < .01; *** when p < .001

Second, students who believed that *science is a more practical subjects* were also more likely to choose the science track in upper secondary school than those who did not. To be specific, having a one-unit increase in the perception that science is a practical subject would increase the odds of choosing the science track by a factor of 2.42 (Exp(B)=2.42). This expected value was revealed to be statistically significant (p <0.001), with variation ranging from 1.49 in the lower bound to 3.92 in the upper bound of the 95% confidence interval (CI). In simple words, those who perceived science at the upper secondary school level as a more practical subject had a 2.42 times greater probability of choosing the science track in upper secondary school.

Within this theme, the qualitative results further explain that the sub-construct of attitudes towards science, science as a practical subject, had a big effect on students' choice of the science track. Students (34.8%) in this group felt that the science track was a good choice for them because of their positive attitudes towards its practicality, as seen in the following student's statement:

> I enjoy studying science because it is about something practical. For example, when the teacher taught us about waves, at first we thought waves were related to being seasick, but when he told us that we could discover a lot of things from a wave, such as that sound and light also have waves, then we [students] felt it was interesting, as we learnt something we had never known before.

Third, in terms of plan to major in STEM, the variable was measured using a dichotomous response (whether students planned to major in STEM or non-STEM). The analysis revealed that students who *plan to major in STEM* in higher education are more likely to choose the science track at the upper secondary school. A change in a unit of plan to major in STEM increases the odds of choosing the science track by a factor of 2.40 (Exp(B)=2.40). This expected value was statistically significant (p <0.001), with variation ranging from 1.47 in the lower bound to 3.92 in the upper bound of the 95% CI.

Within this theme, those who chose the science track had a stronger future plan than those who chose the social science track. Students (40%) recounted that future plan in science contributed substantially to their choice of the science track. They explained that they chose the science track at upper secondary school because they wished to pursue science or STEM majors in higher education:

> I chose the science track because I want to study mathematics more, and information technology [the major I will pursue] requires more mathematics and physics. If I am not good at these subjects, I cannot do well in information technology. So, I am taking this track because I want to build my ability to pursue in STEM.

When they choose the science track, students can enhance their science and mathematics skills, which will enable them to pursue STEM majors in higher education. For one, to be admitted in a STEM major, students must have high scores in science and mathematics. For another, to study in a STEM major, students must have a strong background in science and mathematics. "I chose the science track because in the future, I want to pursue science [to become a doctor], so I have to study science more than social science in upper secondary school."

Fourth, *interest in science at school*, one of the constructs of attitudes towards science, was found to be a significant predictors of upper secondary school students' choice of the science track. The analysis highlighted that the greater interest the students have in science at school, the more likely they are to choose the science track (Exp(B)=1.96, $p < 0.01$). Simply explain, a one-unit increase in students' interest in science at school generates the increase in the odds of choosing the science track by a factor of 1.96 times higher than their counterparts at upper secondary school.

Under this construct, it is also interesting to note that the qualitative interviews provided dept explanation that interest in science at school is crucial to igniting students' interest in science. Students (54%) pursue science or switch from science to the social science could be caused by a lack of interest in science at school. In terms of this category, students felt that a large amount of work in science decreased their interest in it. Students who chose the social science track expressed that they made their choice due to their low interest in science subjects, such as in the following quote:

> Social science subjects are easy; we just memorize the lessons, and we pass the exam. However, science subjects, need a lot [of effort]. We need to calculate, think deeply, and understand the concepts deeply so that we could do well on exam. Some students think this is too much for them.

Science teachers' instructional practices also affect students' interest in science. Some students did not choose to study science because they lack interest in the teachers' instructional practices. One student mentioned, “The teacher’s instructional practices make the subject seem difficult. It is not because of the students, but because of the teaching”.

Another student who switched from science to the social science track highlighted the effect of a mathematics teacher and his teaching practices on her interest in science. She lost interest in science because of her low interest in teachers and their instructional practices:

> In grade 10^{th} I was good at mathematics. I could do the mathematics exercises well, but when I entered grade 11^{th}, I could not understand his explanations. He explained things very slowly. We [the students] just sat and listened, but we could not understand. Then I changed to the social science track.

Last, measured in the number of hours students spent self-studying weekly, *hours spent self-studying chemistry and mathematics* had a significant influence on the probability of choosing the science track at upper secondary school. Statistically speaking, an increase in one hour spent self-studying chemistry subject increases the odds of choosing the science track by 1.52 times, while the same increase in hours spent self-studying mathematics increases the odds of choosing the science track by a factor of 1.34 times. Hence, this finding revealed that the more hours the students spend self-studying chemistry and mathematics, the more likely they are to choose the science track at upper secondary school.

This finding sounds surprising, but a follow-up investigation revealed that students who chose the science track needed to spend much more time not only doing homework, but also taking private classes in science and mathematics. For the baccalaureate examination, students in the science track need to take all science and mathematics, so they need to spend more time enhancing their academic achievement by not only having more time at school, but also more time practicing the exercises and more time for private classes. Common themes among the respondents (40%) demonstrated this tendency. One student said, “Students in the science track spend a lot of time studying, there is no time for going out…Students in the social science track do not need to spend time taking private classes like us; they have more time, time for gaming, especially for lazy students”.

More interestingly, the group of students who chose and remained in the science track at upper secondary school explained that because science and mathematics are difficult, they have to spend most of their free time studying. The students clarified their group’s sentiment that:

> In science class, because it is hard, especially on the exam, we often use most of our free time for study rather than play. When we study, we often spend time together doing exercises given by the teachers and we help explain each other.

5.2.3.2 Family factors

As illustrated in Table 5.6, the inclusion of one's family background and the upper secondary school supports factors (in the second and third models) increased the effect size of most variables in the first model, respectively. Although subject choice could be due to individual preference, family background and encouragement, as well as school experience and support, still play indispensable roles in Cambodian upper secondary school students' likelihood of choosing the science track.

Table 5.6: Family-level factors that predicted students' choice of the science track

Model 2: Family Level Factors	B(SE)	95.0% C.I. for EXP(B)		
		Lower	Exp(B)	Upper
Constant	-12.01(2.95)***		.00	
Mother's education level	.40(.18)**	1.15	1.65	2.36
Cox & Snell R Square	.016			
Nagelkerke R Square	.018			

Note: ** when p < .01; *** when p < .001

Of the variables in the family dimension, the *mother's education level* contributed to the significant value of children choosing the science track (Exp(B)=1.65, p <0.01). When an important issue (such as students' choice of track) is of concern, parents' last minutes persuasion tended to override students' prior intentions. If the mother's educational level increases by one unit, the odds of a student choosing the science track at upper secondary school increases by 1.65 times higher than students whose mother's education is one unit lower. This expected value was found to be statistically significant (p <0.01), with variation ranging from 1.15 in the lower bound to 2.36 in the upper bound of the 95% CI. More interestingly, in the third model, with the inclusion of upper secondary school factors, *family encouragement and support* also exerted a significant influence on the students' choice of the science track. Statistically, a one-unit increase in family encouragement and support increases the odds of students choosing the science track at upper secondary school by a factor of 1.61 times, (Exp(B)=1.61, $p < .05$).

In terms of the home environment, the students had a few comments, including about parents' education and family encouragement and support. The students (25%) explained that parents' education mattered in their choice of the science track, because if their parents have higher knowledge, they will have a positive perception of science and vice versa. Parents objected to students' choice of the science track if they did not have much knowledge about it. One student said:

> My parents do not know what I am doing. Sometimes they asked me why I need to work from dawn to dusk. I tell them that I am taking science classes at school. Then they ask me why I have to study a lot for the science classes and if the students in these classes will pass the national exam easily. I tell them that I have to study a lot for the science classes, that they will be good for me in terms of going to university and finding a job. They just reply [ehh] [ehh] because they do not have much knowledge in this area as they have little education.

Regarding family encouragement and support, students in the science track need a lot of support from their parents. This could be financial as well as time for their children to study and for extracurricular activities in science. One explained that:

> Another thing when studying in science classes is that we need a lot of support from our parents. Like us, when we study and we have to complete a project, we need not only the financial support, but also time to buy the equipment and to complete the project.

Overall, the inclusion of variables at the family level lowered the effects of hours spent self-studying mathematics, performance in science subjects, science as a practical subject, and future plan in science. Interestingly, they have increased the odds of hours spent self-studying chemistry, interest in science at school, and plan to major in STEM.

5.2.3.3 School factors

Third, from school experiences and support perspective, of the variables included in the regression model, only *upper secondary school location* mattered in students' choice of the science track. The results indicated that students from upper secondary schools in Phnom Penh (urban) are more likely to choose the science track than their counterparts from other (rural) provinces. In statistical terms, a one-unit increase of the students in Phnom Penh upper secondary school results in an increase of about 1.93 times whereby the students choose the science track (Exp(B)=1.93; see Table 5.7 for details).

Statistically, if students study in upper secondary schools in Phnom Penh, their probability of choosing the science track increases by 1.93 times higher than those from rural schools. This expected value was found to be statistically significant (p <0.05), with variation ranging from 1.14 in the lower bound to 3.26 in the upper bound of the 95% CI.

Table 5.7: Upper secondary school-level factors predicted students' choice of the science track

Model 3: School Level Factors	B(SE)	95.0% C.I. for EXP(B)		
		Lower	Exp(B)	Upper
Constant	-11.58(2.94)***		.00	
School location (other province)	.66(.27)*	1.14	1.93	3.26
Cox & Snell R Square	.004			
Nagelkerke R Square	.006			

Note: * when p < .05; *** when p < .001

In sum, the inclusion of the variables at the upper secondary school level has a similar effect to the inclusion of family-level factors on the effects of individual-level variables in relation to the probability of students' choice of the science track at upper secondary school. Simply explain, the inclusion of this model lowered the effects of hours spent self-studying mathematics, performance in science subjects, science as a practical subject, future plan in science. Interestingly, the model increased the odds of the effect of hours spent self-studying chemistry, interest in science at school, and plan to major in a STEM related majors on students' choice of the science track.

5.3 Discussion of key themes for RQ 1

5.3.1 The influence of academic preparedness

The most influential factor at the individual level, consistent with prior studies (e.g., Darolia et al., 2018; Kwak, 2009; Shin et al., 2017; Shin et al., 2018), was performance in science and mathematics subjects. A one-unit increase in performance in science and mathematics leads to an increase of 3.16 times in choosing the science track. This implies that low performance in science and mathematics in particular, and in academic achievement in general, has contributed to the declining trend of students choosing the science track at upper secondary school. Students in the science track need to study science more than those in the social science track, and they need to take all science subjects and mathematics for the national exit examination. Further, since most students do not like (or cannot do well in) science and mathematics (CDRI, 2015), they choose the social science track. One yet interesting reality to help explain this phenomenon is that since 2013, Cambodia's education system (especially upper secondary education) has gone through deep-seated reforms, including the reform of the baccalaureate examination. Under a strict examination policy, *qualified students can pass (in Khmer: អ្នកចេះគឺជាប់)*, but only about 26% of students who took the examination in academic year 2013–2014 were capable of passing the national examination, as compared with the passing rate of approximately 80% over the past decade (MoEYS, 2014b; see Figure 5.1 for details). The percentage has gradually risen in recent academic years.

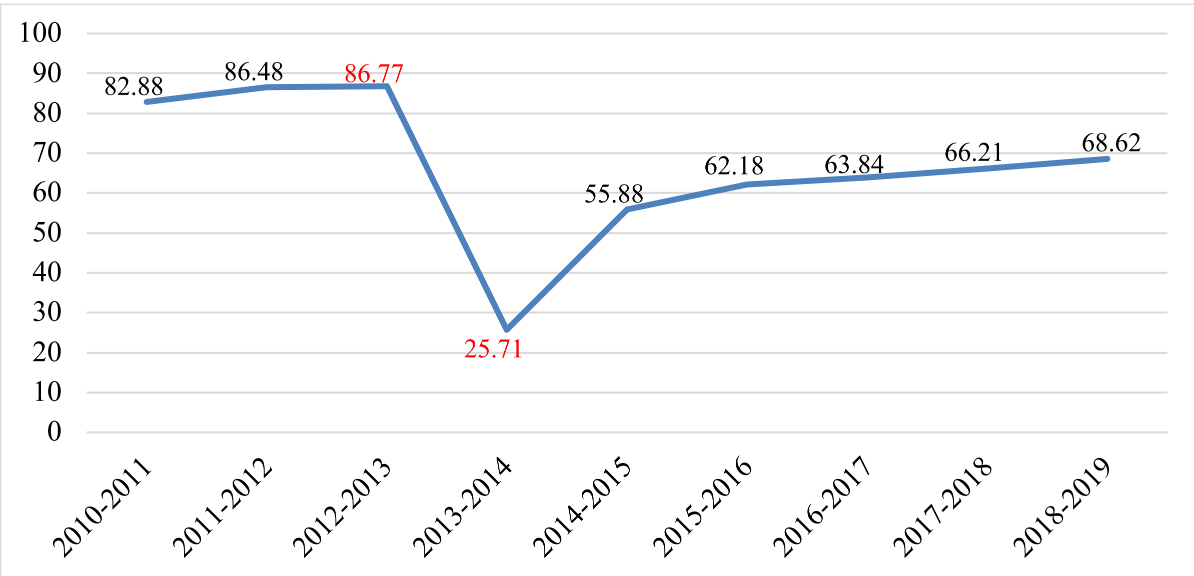


Figure 5.1: Percentage of students that passed the national exit examination from 2011–2019

This sharp decline in the number of students passing the national examination has greatly impacted the choice of track at upper secondary school. Evidently, a closer investigation on the passing rate by study track revealed that on average from 2014–2019, 73% of students in the social science track passed the examination compared to 49% of students in the science track (MoEYS, 2019f). The lower rate of students in the science track passing the national exit examination might have lowered students' self-efficacy in passing it, possibly causing them to switch to the social science track, which has higher passing rate. Furthermore, in addition to overall performance, academic achievement in mathematics and science is of great concern. As evidence, during the 2015 national examination, out of the 83,325 students who took it, only 23.3% passed the mathematics portion, while 41.7% passed the biology portion. Since students in the science track have to take more difficult science and mathematics test on the examination, most students might lower their self-concept and efficacy in science and mathematics subjects and choose the social science track, which is generally perceived as easier, and has a higher percentage in terms of getting a passing grade on the baccalaureate examination. This finding confirms what has been recently found in the Korean context that not only the overall but also the science and mathematics performance are the most significant predictors of students' likelihood of choosing the science track (Paik & Shim, 2013).

5.3.2 The influence of attitudes towards science

Of the attitudes towards science constructs, science as a practical subject and future plan in science are the second and third most influential factors in predicting Cambodian upper secondary school students' choice of the science track. This finding supports the longstanding discussed supposition that weaker attitudes towards science and future participation in science are among the factors that have been reducing students' likelihood of choosing the science track, or causing students to leave science altogether (e.g., Ormerod & Duckworth, 1975; Freedman, 1997; Kind et al., 2007; Osborne et al., 2003; Papanastasiou & Papanastasiou, 2004; Woolnough, 1994b; Woolnough et al., 1997). Students with low self-rated attitudes towards science—including one's perception of science teachers, anxiety toward science, the importance of science, self-esteem in science, motivation towards science, one's enjoyment of science, and the nature of the science classroom environment—are likely to have lower performance in science and lower interest in science-related majors.

In this regard, the declining trend of Cambodian upper secondary school students' interest in science might be explained by the lower attitudes towards science. The students tended to have a low to moderate level for the constructs of attitudes towards science. The most alarming trend entailed science and mathematics self-concepts and the extracurricular activities in science. This finding was consistent with the results of Kao (2019a), who showed that Cambodian upper secondary school students have a lower rating scale on all constructs of attitudes towards science. As illustrated in Figure 5.2, in the two observations, these two constructs were lower. This is really interesting, as the students tended to believe that science is important for society, but because they have lower science and mathematics self-concepts, they also tend to have lower future plan in science. This trend might therefore have a significant influence on students' performance in science and mathematics and their interest in choosing the science track at upper secondary school.

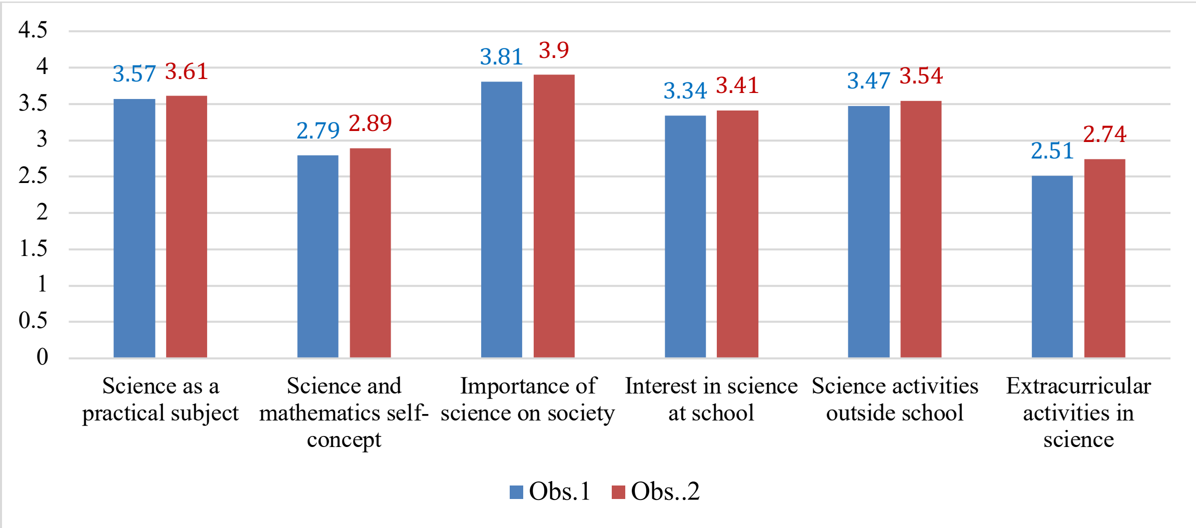


Figure 5.2: Trends of attitudes towards science constructs: Observations 1 and 2

5.3.3 Gender: A contrasting perspective

Contradict to the other studies (e.g., Dustmann, 2004; Myeong & Crawley, 1993; Li & Kuan, 2018; Paik & Shim, 2013) this study found that gender did not have a significant influence on students' choice of the science track. However, this seems to confirm what other studies have discovered (Kim, 2006; Stokking, 2000): Gender on its own is not a significant predictor of one's persistence in science. Contextually, female students' track choice is not tightly connected to their major or career choice in science, as in the case of male students. Female students' choice of the science track at upper secondary school might be due to the perception that the science track will provide them with an open pathway to various majors in higher education. For example, in higher education level, female students are not likely to choose science-related majors compared to male students (Kao & Shimizu, 2019). This finding might serve as a counter argument to the culturally embedded view among general public that female students are usually not in favour of science-related courses. Further explanation could be supported by the qualitative finding that all of the 16 females participated in the interviews mentioned that gender stereotypes are not involved in choosing the science track at upper secondary school. Two students stated *"Mostly only female students are in the science track. Male students seemed to be lazy; they enjoy going out, so they switch to the social science"*. In short, it could be concluded that students' gender does not play a considerable role in the students' choice of the science or social science track at upper secondary school.

5.3.4 The crucial role of the family environment

Although subject choice could be due to individual preferences, family background and encouragement, as well as school experiences, support, and the environment are contributing indispensable influences in students' choice of the science track. Family encouragement and support had the most influential effect. An increase in this variable increases the odds of students choosing the science track at upper secondary school by 1.61 times, (Exp(B)=1.61). Consistent with prior studies (e.g., Ekmekci et al., 2019; Shimpkins et al., 2015; Shin et al., 2015), current study found that the family environment tended to be a significant untapped resource of support for students. For example, parents' provision of enriching experiences at home (such as playing mathematics games, hobbies, science activities, and encouragement to take science classes and complete science homework) is central to students' interest in science, knowledge, and skills. Family encouragement and support propels students' persistence in science since this variable is related to the quality of the family interactions, which are intrinsically focused on or emphasized mastery goals. This effect might be due to what Ekmekci (2019) highlighted as the Pygmalion factors, which refers to an improvement in a person's performance when someone close to him/her expects him/her to perform well or to achieve more in something. Thus, students feel motivated and secured when they receive encouragement and support from their families. Contextually, as some students in science class need to take a lot of private classes, they need to have a good balance of not only financial resources, but also time allowed to study at home. Hence, family encouragement and support in science plays an indispensable role in motivating students to perform well in science and mathematics and inspiring their interest in the science track.

Most notably, the mother's education level contributed significantly to the odds of students choosing the science track (Exp(B)=1.07) at upper secondary school. The study positioned on what has been debated that when an important issue such as students' track choice is of concern, parents' last minutes persuasion tended to override students' prior intentions. Consistent with the findings by previous research (e.g., Dustmann, 2004; Kinyota, 2013; Miller & Kimmel, 2012; Shin et al., 2017), current study also posited that aspects of family background, especially educated mothers, would lead to a higher level of encouragement towards children to enrol in the science track, versus a family with a mother that has less education. This result is in line with the work of Arslan (2016), Kwak (1993), and Paik and Shim (2013) who revealed that the mother's education level is more effective than the father's education level in terms of students choosing science. The in-depth analysis of the data also revealed that, in addition to encouragement and support from one's parents, the female students tended to have higher encouragement and support from their parents (*M*=3.37, *SD*=.064) than male students (*M*=3.34, *SD*=.708). In the Cambodian context, there might be a few anecdotes to explain this phenomenon. First, Cambodian children traditionally tend to have closer connections with their mothers than their fathers. Also, when mothers have higher education level, they might not only have more financial and academic resources to support their children, but also value science more and be aware of current labour market demands. Consequently, when their children discussed their educational choices, these mothers will be more likely to persuade their children to choose science. This might especially be unique in Asian culture, where family influence still matters a lot in students' educational choice. Thus, choosing the science track still recount on the effects of encouragement and support from one's family, especially when the mother has a higher level of education.

5.3.5 Geographical area

From the standpoint of school experiences and a supportive environment, the study indicated that students from upper secondary schools in Phnom Penh (urban) were more likely to choose the science track than students from schools in the other (rural) provinces. Put in statistical terms, a one-unit increase of the students in Phnom Penh upper secondary school leads to an increase of 1.93 in students choosing the science track (Exp(B)=1.93). This finding was consistent with Woolnough (1994a), who claimed that, due to some disadvantages, students from the rural areas have less interest in science than those from the urban areas. More significantly, the data also revealed that students in upper secondary school in the (rural) provinces have lower performance in science subjects (*M*=2.23, *SD*=.03) compares to (*M*=2.43, *SD*=.04) students in Phnom Penh *($t=-3.03$; $p<0.01$).* In contrast, performance in social subjects was higher (*M*=3.00, *SD*=.04) for students in the (rural) provinces than (*M*=2.97, *SD*=.04) for students in Phnom Penh. This supports one of the current study results whereby students who scored high in science and mathematics tended to choose the science track at higher odds than their counterparts. The diverse characteristics of the upper secondary schools in urban and the rural zones regarding the quality of the teachers, the availability of teaching resources, and school culture might also contribute to this phenomenon (Eng & Szmodis, 2015; Woolnough, 1994b). Some Cambodian upper secondary schools might still be at disadvantage in accessing enough qualified teachers and teaching resources (CDRI, 2015); this will be a burden for rural counterparts. Further, although students in the non-urban areas seemed to rate higher on attitudes towards science than those from urban areas (Kao, 2019a), academic performance (especially in science and mathematics) might have more of an impact on their decision to take the science or social science track at upper secondary school. As students in Phnom Penh performed higher in science and mathematics than those from the provinces, about 87% of the students in Phnom Penh chose the science track compared to that of 81% and 77% in Battambang and Kampong Cham, respectively (MoEYS, 2019c).

5.4 Concluding remarks

The current study could lead us to draw the following conclusions. First, students' performance in science subjects, attitudes towards science (the practicality of science subjects [facts and fun] and self-interest in science at school), and future plan to major in STEM influenced students toward choosing the science track. In the same vein, adding to the battery of knowledge on students' choice of the science track, their engagement in their academic pursuits by spending more time self-studying at home (particularly chemistry and mathematics) signified their likelihood of choosing the science track. Second, reflecting the cultural influence from one's family on students' choice, family encouragement and support, (which might be a unique cultural influence in Asian families, especially ones with higher educated mothers) contributed to the variance that explains students' choice of the science track. Third, students who were studying in upper secondary school in Phnom Penh choose the science track more than their rural counterparts. In sum, the results contributed to the knowledge that the worrisome declining trend of students in the science track is due not only to individual academic ability and attitudinal variables, but also to cultural influence from one's family and the conditions of upper secondary schools.

CHAPTER SIX: TRENDS AND PATTERNS OF TIME-VARYING COVARIATES: FINDING II

To investigate the effects of different tracks at upper secondary school on Cambodian students' aspirations of STEM majors in higher education, it is crucial to understand the trends and patterns of the time-varying covariates of the students who chose different tracks for one academic year. The purpose of this chapter is thus to investigate the trends and patterns of the time-varying covariates across one academic year. This chapter begins by reviewing the method (including the samples and data analysis procedure), followed by the results of the trends and patterns of the covariates in Observation 1, and those of Observation 2. The chapter proceeds with the trends and patterns of the covariates across the two observations, so as to determine if there was any significant change from observations 1 to 2 as well as significant changes in the time-varying covariates across the two observations as a function of gender, school location, and study track. The discussion and conclusion responding to *Research Question 2* serve as the closure of the current chapter.

In this chapter, the researcher addressed the following research question as follow.

RQ 2: What are the trends and patterns of the time-varying covariates for students who attended in different tracks at upper secondary school for one academic year?

6.1 Method for RQ 2

6.1.1 Samples

Since the purpose of the second study was to scrutinize the trends and patterns of time-varying covariates, the data from the first and second waves were used in the analysis. While the first wave was conducted with early grade 11^{th} students, the second wave was conducted with late grade 11^{th} students. Although there were 752 students in the first wave, because some students dropped out of school and some moved to the other schools, the retention rate for the second wave was 93.09. Therefore, only 700 students participated in the second wave. To respond to the purpose of the current study, the researcher only used the data from the 700 respondents who participated in both the first and second waves in the data analysis to answer *Research Question 2*.

6.1.2 Data analysis method

To address research question 2 which was to illustrate the trends and patterns of time-varying covariates, the data were analyzed in two-steps process. First, to find if students who chose science track in traditional and NGS schools performed better on the time-varying covariates than students who chose the social science track, independent sample t-test and analysis of variance (ANOVA) were employed. The analysis compared the mean difference between these tracks, gender, and school location. Further, since there were two waves of data collection, analysis of covariance (ANCOVA) was employed to determine if there was any significant effect resulting from enrolling in the science track as compared to the social science track when controlling for the first wave data. Therefore, the baseline year mean score of the observation at the beginning of the academic year (*Observation 1*) was used as the covariates. Second, dependent/pair sample t-test and repeated ANOVA were employed as the second data analysis step to determine if the levels of time-varying covariates for students who chose the science track for one academic year compared to their counterparts in the social science track. Table 6.1 displays the time-varying covariates included in the analysis.

Table 6.1: Time-varying covariates included in the analysis for Finding II

Variables	**Data type**	**Range**
Individual Level Factors		
Performance in science and mathematics	Scale	1-5
Science and mathematics self-efficacy	Scale	1-5
Science and mathematics outcome expectations	Scale	1-5
Science as a practical subject	Scale	1-5
Science and mathematics self-concept	Scale	1-5
Importance of science in society	Scale	1-5
Interest in science at school	Scale	1-5
Science activities outside school	Scale	1-5
Extracurricular activities in science	Scale	1-5
Future plan in science	Scale	1-5
Family Level Factors		
Family encouragement and support	Scale	1-5
School Level Factors		
Science and mathematics teachers' support	Scale	1-6
Interactive science and mathematics lessons	Scale	1-4

Prior to the main analysis, data cleaning and assumptions checking was made for the analysis of independent sample *t-test* and Analysis of Covariance (ANCOVA) as the two tests assume homogeneity of variance. To test this assumption, *Leven's tests* were applied. If a Leven significance level was less than 0.05, then the assumption of homogeneity of variance was violated. However, from the assumption checking test, no Leven significance level was less than 0.05. Therefore, the two tests were applicable for analyzing the two waves data. Moreover, where significant differences occurred, Cohen's effect sizes—*Cohen's d* for the independent and dependent sample t-test and *partial eta*^{2}(η_p^2) for ANCOVA and repeated ANOVA—were calculated to evaluate the strength of the relationship. The interpretation of these effect sizes was based on *Cohen's d* and *eta*^{2} descriptors. According to Cohen (1988), the categorized magnitudes of effect size are: $d < 0.20$ indicates a very small effect, $d = 0.20$ denotes a small effect, $d = 0.50$ as medium effect, $d = 0.80$ is large effect, and $d > 1.00$ is very large effect (Sawilowsky, 2009). Moreover, according to Fritz, Morris, and Richler (2012) $\eta_p^2 = 0.01$ means small effect, $\eta_p^2 = 0.06$ means medium effect, and $\eta_p^2 = 0.14$ means large effect.

6.2 Trends and patterns: Observation 1

6.2.1 Trends of time-varying covariates: Observation 1

Table 6.2 depicts the trends of the time-varying covariates in Observation 1. The overall quantitative trends were discussed on performance in science and mathematics (one factor), science and mathematics self-efficacy (one factor), science and mathematics outcome expectations (one factor), attitudes towards science (six factors), family encouragement and support (one factor), support from science and mathematics teachers (one factor), and the interactive science and mathematics lessons (one factor) at the upper secondary school level.

As mentioned, the factors were generated from the principal axis factoring with Varimax and Keiser normalization in rotation. The overall trends of the time-varying covariates are illustrated by the mean score of each variable (factor). The variables were measured on a scale from 1 (the lowest score) to 5 (the highest score), except for science and mathematics teachers' support, which was measured on a six-point Likert scale from 1 (the lowest) to 6 (the highest), and interactive science and mathematics lessons, which was measured on a four-point-Likert scale from 1 (the lowest) to 4 (the highest). Overall, the students rated lower than average on performance in science and mathematics subjects ($M = 2.36$, $SD = .85$). On the other hand, they tended to rate from a moderate to high level on science and mathematics self-efficacy (*M* = 3.01, *SD* = .67) and science and mathematics outcome expectations (*M* = 3.85, *SD* = .63).

Table 6.2: Trends of time-varying covariates: Observation 1

Constructs	N	Min.	Max.	M	SD	Skewness	Kurtosis
Performance in science and mathematics	700	1	5	2.36	0.85	0.58	-0.06
Science and mathematics self-efficacy	700	1	5	3.01	0.67	-0.21	-0.03
Science and mathematics outcome expectations	700	1	5	3.85	0.63	-0.70	1.19
Science as a practical subject	700	1	5	3.57	0.76	-0.66	0.58
Science and mathematics self-concept	700	1	5	2.79	0.71	-0.04	0.17
Importance of science in society	700	1	5	3.81	0.63	-0.71	1.48
Interest in science at school	700	1	5	3.34	0.77	-0.50	0.84
Science activities outside school	700	1	5	3.47	0.67	-0.35	0.66
Extracurricular activities in science	700	1	5	2.51	0.76	0.24	-0.11
Future plan in science	700	1	5	3.33	1.01	-0.51	-0.27
Family encouragement and support	700	1	5	3.38	0.67	-0.15	0.41
Science and mathematics teachers' support	700	2	6	4.16	0.87	-0.17	-0.35
Interactive science and mathematics lessons	700	1	4	2.85	0.52	-0.03	-0.10

Next is the trends among the sub-constructs of attitudes towards science. The most noticeable attitudes constructs that the students exhibited higher positive attitudes towards was the importance of science in society (*M* = 3.81, *SD* = .63), followed by science as a practical subject (*M* = 3.57, *SD* = .76), science activities outside school (*M* = 3.47, *SD* = .67), and interest in science activities at school (*M* = 3.34, *SD* = .77). However, the variables which Cambodian students expressed lower attitudes towards were science and mathematics self-concepts (*M* = 2.79, *SD* = .71) and extracurricular activities in science (*M* = 2.51, *SD* = .76).

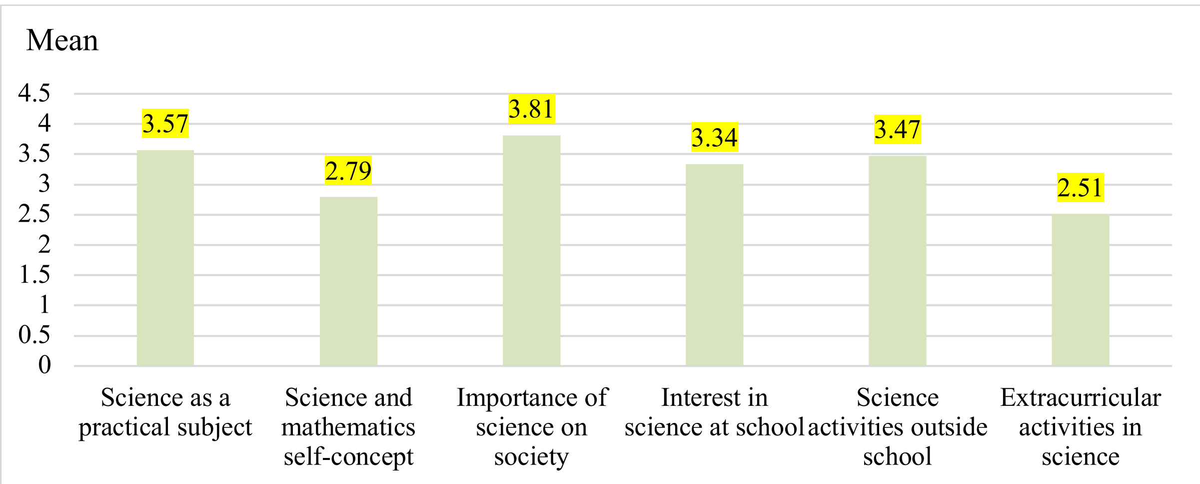


Figure 6.1: Mean of attitudes towards science constructs in Observation 1

The trends of Cambodian students' attitudes towards science were interesting, as expected. While most students tended to believe that science plays a crucial role in society and that they are more likely to be interested in the practical work of science and science activities outside school, they seemed to have a lower self-concept in science and science learning which, as a result, influenced their extracurricular activities in science. (See Figure 6.1).

Last, it is significant to note that the students rate at a moderate level for future plan in science (*M* = 3.33, *SD* = 1.01), encouragement and support from their families (*M* = 3.38, *SD* = .67), science and mathematics teachers' support (*M* = 4.16, *SD* = .87), and interactive science and mathematics lessons (*M* = 2.85, *SD* = .52). Of the time-varying covariates, the students seemed to rate science and mathematics outcome expectations, science as a practical subject, and the importance of science in society at high level. However, they tended to rate science self-efficacy, science and mathematics self-concepts, interest in science at school, science activities outside school, extracurricular activities in science, future plan in science, support from one's family and science and mathematics teacher, and interactive science and mathematics lessons at a moderate level, and performance in science and mathematics at a low level.

6.2.2 Patterns of time-varying covariates: Observation 1

This section explains whether the previously discussed time-varying covariates measured in Observation 1, were differentiated by the three demographic attributes of gender, school location, and study track.

6.2.2.1 Patterns across gender

Table 6.3 illustrates the patterns of time-varying covariates in observation 1 across gender differences. Overall, for Observation 1, it is surprising to note that male students had a lower mean score than female students for most of the constructs, except for science and mathematics self-concepts, importance of science in society, science activities outside school, and extracurricular activities in science. The independent sample t-test revealed that although female students exhibited a higher mean score than their male peers in Observation 1, the differences were not statistically significant. In sum, male and female students tended to have a slightly equal level of science and mathematics performance, science and mathematics self-efficacy, science and mathematics outcome expectations, attitudes towards science, family encouragement and support, support from science and mathematics teachers, and interactive science and mathematics lessons in Observation 1.

Table 6.3: Time-varying covariates by gender

Constructs	**Gender**	**Mean**	**SD**	***t***	**Sig.**	**ES**
Performance in science and mathematics	Male	2.35	.88	-.30	.76	--
	Female	2.37	.82			
Science and mathematics self-efficacy	Male	3.01	.67	.03	.97	--
	Female	3.01	.67			
Science and mathematics outcome expectations	Male	3.84	.66	-.36	.72	--
	Female	3.85	.60			
Science as a practical subject	Male	3.56	.82	-.38	.70	--
	Female	3.58	.71			
Science and mathematics self-concept	Male	2.80	.74	.54	.59	--
	Female	2.77	.67			
Importance of science in society	Male	3.83	.67	.65	.51	--
	Female	3.79	.60			
Interest in science at school	Male	3.29	.84	-1.68	.09	--
	Female	3.39	.71			
Science activities outside school	Male	3.50	.69	1.08	.28	--
	Female	3.44	.66			
Extracurricular activities in science	Male	2.51	.70	.17	.86	--
	Female	2.50	.79			
Future plan in science	Male	3.29	1.05	-.98	.33	--
	Female	3.36	.98			
Family encouragement and support	Male	3.37	.70	-.47	.64	--
	Female	3.39	.65			
Science and mathematics teachers' support	Male	4.13	.85	-.90	.37	--
	Female	4.18	.89			
Interactive science and mathematics lessons	Male	2.84	.53	-.11	.90	--
	Female	2.84	.51			

6.2.2.2 Patterns across school location

From the perspective of school location, Table 6.4 shows whether the time-varying covariates in Observation 1 were differentiated by the three provinces (Phnom Penh, Kampong Cham, and Battambang). One-way Analysis of Variance (ANOVA) revealed that there was a statistically significant difference among the three areas of school location on: performance in science and mathematics, $F(2,696) = 7.56$, $p = .001$; science and mathematics self-efficacy, $F(2,696) = 6.10$, $p = .002$; science as a practical subject, $F(2,696) = 6.94$, $p = .001$; science and mathematics self-concepts, $F(2,696) = 4.78$, $p = .009$; interest in science at school, *F*(2,696) = 3.05, *p* = .048; science activities outside school *F*(2,696) = 3.65, *p* = .026; extracurricular activities in science, *F*(2,696) = 12.21, *p* = .000; future plan in science, *F*(2,696) = 8.35, *p* = .000; science and mathematics teachers' support *F*(2,696) = 14.48, *p* = .000; and interactive science and mathematics lessons, *F*(2,696) = 4.97, *p* = .007.

Table 6.4: Time-varying covariates by school location

Constructs	n	Location	Mean	SD	*F*	Sig.	Eta^2
Performance in science and mathematics	330	PP	2.46	.91			
	195	KC	2.38	.82	7.56	.001**	.02
	175	BTB	2.15	.73			
Science and mathematics self-efficacy	330	PP	3.01	.66			
	195	KC	3.12	.62	6.10	.002**	.02
	175	BTB	2.88	.73			
Science and mathematics outcome expectations	330	PP	3.85	.67			
	195	KC	3.92	.56	2.47	.085	.00
	175	BTB	3.77	.60			
Science as a practical subject	330	PP	3.64	.80			
	195	KC	3.61	.63	6.94	.001**	.02
	175	BTB	3.38	.79			
Science and mathematics self-concept	330	PP	2.77	.70			
	195	KC	2.91	.66	4.78	.009**	.01
	175	BTB	2.69	.74			
Importance of science in society	330	PP	3.82	.68			
	195	KC	3.83	.57	.81	.446	.00
	175	BTB	3.76	.60			
Interest in science at school	330	PP	3.34	.77			
	195	KC	3.43	.66	3.05	.048*	.00
	175	BTB	3.23	.86			
Science activities outside school	330	PP	3.44	.71			
	195	KC	3.60	.60	3.65	.026*	.01
	175	BTB	3.41	.67			
Extracurricular activities in science	330	PP	2.65	.77			
	195	KC	2.42	.70	12.21	.000***	.03
	175	BTB	2.33	.73			
Future plan in science	330	PP	3.32	.96			
	195	KC	3.55	.96	8.35	.000***	.02
	175	BTB	3.13	1.13			
Family encouragement and support	330	PP	3.36	.66			
	195	KC	3.38	.67	.26	.770	.00
	175	BTB	3.41	.70			
Science and mathematics teachers' support	330	PP	3.10	.86			
	195	KC	4.41	.73	14.48	.000***	.04
	175	BTB	4.18	.96			
Interactive science and mathematics lessons	330	PP	2.79	.54			
	195	KC	2.93	.44	4.97	.007**	.01
	175	BTB	2.86	.53			

Note: - PP=Phnom Penh; KC=Kampong Cham; BTB=Battambang; Eta^2 = *Partial Eta-squared*
- * when p < .05; ** when p < .01; *** when p < .001

Table 6.5 outlines the results of the post-hoc multiple comparison test or Tukey HSD test (a test of homogeneity of variances for each construct $p > .05$) regarding the differences in the impact of school location on the constructs investigated. Students from schools located in Phnom Penh rated significantly higher than those from schools located in Kampong Cham on extracurricular activities in science, but significantly lower on future plan in science, science and mathematics teachers' support, and interactive science and mathematics lessons. Moreover, students from schools in Phnom Penh performed better than those who were from schools in Battambang on performance in science and mathematics, science as a practical subject, and extracurricular activities in science, but lower on science and mathematics teachers' support and interactive science and mathematics lessons.

Table 6.5: Post-hoc Tukey HSD test on the differences in school location on the constructs

Constructs	Location (I)	Location (J)	I-J	Sig.
Performance in science and mathematics	PP	KC	.09	.491
		BTB	.30	.000***
	KC	BTB	.22	.034*
Science and mathematics self-efficacy	PP	KC	-.12	.132
		BTB	.13	.106
	KC	BTB	.24	.001**
Science as a practical subject	PP	KC	.03	.911
		BTB	.25	.001**
	KC	BTB	.23	.011*
Science and mathematics self-concept	PP	KC	-.14	.060
		BTB	.07	.490
	KC	BTB	.22	.008**
Interest in science at school	PP	KC	-.09	.362
		BTB	.10	.322
	KC	BTB	.20	.036*
Science activities outside school	PP	KC	-.13	.067
		BTB	.04	.807
	KC	BTB	.17	.034*
Extracurricular activities in science	PP	KC	.23	.002**
		BTB	.32	.000***
	KC	BTB	.09	.497
Future plan in science	PP	KC	-.23	.028*
		BTB	.19	.101
	KC	BTB	.42	.000***
Science and mathematics teachers' support	PP	KC	-.41	.000***
		BTB	-.19	.048*
	KC	BTB	.23	.031*
Interactive science and mathematics lessons	PP	KC	-.14	.005**
		BTB	-.07	.312
	KC	BTB	.07	.338

Note: * when p < .05; ** when p < .01; *** when p < .001

Lastly, the sampled schools in Kampong Cham performed higher than schools in Battambang on science and mathematics, science and mathematics self-efficacy, science as a practical subject, science and mathematics self-concepts, interest in science at school, science activities outside school, future plan in science, and science and mathematics teachers' support.

6.2.2.3 Patterns across study tracks

Academically, inquiry into how different groups of students exhibited their science and mathematics performance, science self-efficacy, attitudes towards science, family and science and mathematics teachers' support, and science learning experiences was also made with reference to their study tracks at upper secondary school. As mentioned earlier, starting in academic year 2010, MoEYS introduced the tracking system, requesting all grade 10th students to choose either the science or the social science track for the 11th and 12th grades. Also, just as recently, another type of school, NGS (which only offers science track classes) were opened. More interestingly, the science track in NGS was streamed into the focused classes of mathematics, physics, biology, and chemistry so as to build students' competence in STEM majors.

Table 6.6 indicates the effects of choosing different tracks at upper secondary school on the time-varying covariates in Observation 1. As could be seen, in all instances, the level of the constructs was differentiated by the three types of tracks the students attended. Overall, students in the science track at NGS performed higher than those in the science track and the social science track in traditional schools. To be precise, students from NGS showed a significant difference between students from the science track and the social science track regarding their performance in science and mathematics, science and mathematics self-efficacy, science and mathematics outcome expectations, all sub-constructs of attitudes towards science, future plan in science, family supports and encouragement, science and mathematics teachers' support, and interactive science and mathematics lessons, with $p < .001$ and the effect size of the *Partial Eta-squared* ranging from .04 to .30. Of the investigated constructs, the strongest significant effects emphasized performance in science and mathematics, science as a practical subject, and science and mathematics self-efficacy. The constructs that revealed weaker effects were support from science and mathematics teachers, interactive science and mathematics lessons, and science and mathematics outcome expectations, and the importance of science in society.

Table 6.6: Time-varying covariates by track

Constructs	**Track**	**Mean**	**SD**	***F***	**Sig.**	**Eta^2**
	NGS	3.04	.91			
Performance in science and mathematics	Science	2.49	.69	151.89	.000***	.30
	Social	1.80	.58			
	NGS	3.28	.61			
Science and mathematics self-efficacy	Science	3.25	.56	118.96	.000***	.25
	Social	2.55	.59			
	NGS	3.96	.58			
Science and mathematics outcome expectations	Science	3.99	.54	27.32	.000***	.07
	Social	3.62	.68			
	NGS	4.04	.56			
Science as a practical subject	Science	3.77	.56	138.59	.000***	.29
	Social	3.05	.76			
	NGS	3.04	.64			
Science and mathematics self-concept	Science	3.04	.59	99.61	.000***	.22
	Social	2.35	.65			
	NGS	4.02	.63			
Importance of science in society	Science	3.88	.54	26.62	.000***	.07
	Social	3.60	.65			
	NGS	3.58	.58			
Interest in science at school	Science	3.65	.60	108.61	.000***	.24
	Social	2.85	.80			
	NGS	3.60	.67			
Science activities outside school	Science	3.60	.60	24.56	.000***	.07
	Social	3.24	.69			
	NGS	2.90	.78			
Extracurricular activities in science	Science	2.48	.74	31.29	.000***	.08
	Social	2.31	.68			
	NGS	3.69	.78			
Future plan in science	Science	3.73	.80	113.49	.000***	.25
	Social	2.67	1.01			
	NGS	3.68	.62			
Family encouragement and support	Science	3.53	.58	72.35	.000***	.17
	Social	3.01	.64			
	NGS	4.39	.80			
Science and mathematics teachers' support	Science	4.21	.83	13.65	.000***	.04
	Social	3.95	.91			
	NGS	3.02	.46			
Interactive science and mathematics lessons	Science	3.99	.49	14.27	.000***	.04
	Social	3.63	.55			

Note: - Eta^2 = *Partial Eta-squared*

- Eta^2 of 0.01 = small; 0.06 = medium; 0.14 = large

- * when $p < .05$; ** when $p < .01$; *** when $p < .001$

Table 6.7: Post-hoc Tukey HSD test on the differences in study track on the constructs

Constructs	Track (I)	Track (J)	I-J	Sig.
Performance in science and mathematics	NGS	Science	.54	.000***
		Social	1.23	.000***
	Science	Social	.69	.000***
Science and mathematics self-efficacy	NGS	Science	.03	.868
		Social	.72	.000***
	Science	Social	69	.000***
Science and mathematics outcome expectations	NGS	Science	-.03	.890
		Social	.33	.000***
	Science	Social	.36	.000***
Science as a practical subject	NGS	Science	.26	.000***
		Social	.99	.000***
	Science	Social	.73	.000***
Science and mathematics self-concept	NGS	Science	-.002	.999
		Social	.69	.000***
	Science	Social	.69	.000***
Importance of science in society	NGS	Science	.14	.069
		Social	.42	.000***
	Science	Social	.29	.000***
Interest in science at school	NGS	Science	-.07	.547
		Social	.73	.000***
	Science	Social	.80	.000***
Science activities outside school	NGS	Science	-.003	.998
		Social	.36	.000***
	Science	Social	.36	.000***
Extracurricular activities in science	NGS	Science	.42	.000***
		Social	.58	.000***
	Science	Social	.16	.023*
Future plan in science	NGS	Science	-.04	.895
		Social	1.02	.000***
	Science	Social	1.06	.000***
Family encouragement and support	NGS	Science	.15	.037*
		Social	.66	.000***
	Science	Social	.51	.000***
Science and mathematics teachers' support	NGS	Science	.17	.111
		Social	.44	.000***
	Science	Social	.27	.001**
Interactive science and mathematics lessons	NGS	Science	.17	.003**
		Social	.28	.000***
	Science	Social	.19	.035*

Note: * when p < .05; ** when p < .01; *** when p < .001

Post-hoc multiple comparison test or Tukey HSD test (a test of homogeneity of the variances for each construct with $p > .05$) of the differences in the impact of one's study track on the constructs was investigated. As seen in Table 6.7, students in NGS performed better than students in the science track, but only on performance in science and mathematics, science as a practical subject, extracurricular activities in science, family encouragement and support, and interactive science and mathematics lessons. However, students in NGS exhibited significantly higher effects than student in the social science track on all constructs measured. In the same vein, science track students performed significantly higher than their counterparts from the social science track on all constructs.

6.3 Trends and patterns: Observation 2

6.3.1 Trends of time-varying covariates: Observation 2

Table 6.8 portrays the trend of the time-varying covariates in Observation 2. Overall Cambodian upper secondary school students exhibited a low to moderate level on performance in science and mathematics, science and mathematics self-efficacy and outcome expectations, attitudes towards science sub-constructs, family encouragement and support, science and mathematics teachers' support, and interactive science and mathematics lessons.

Table 6.8: Trends of time-varying covariates: Observation 2

Constructs	N	Min	Max	M	SD	Skewness	Kurtosis
Performance in science and mathematics	700	1	5	2.50	0.77	0.35	-0.49
Science and mathematics self-efficacy	700	1	5	3.08	0.65	-0.13	0.02
Science and mathematics outcome expectations	700	2	5	3.88	0.58	-0.45	0.58
Science as a practical subject	700	1	5	3.61	0.69	-0.42	0.47
Science and mathematics self-concept	700	1	5	2.89	0.66	0.04	0.09
Importance of science in society	700	2	5	3.90	0.57	-0.15	0.48
Interest in science at school	700	1	5	3.41	0.67	-0.32	0.90
Science activities outside school	700	1	5	3.54	0.67	-0.44	0.98
Extracurricular activities in science	700	1	5	2.74	0.78	0.19	-0.07
Future plan in science	700	1	5	3.20	0.70	-0.32	0.15
Family encouragement and support	700	1	5	3.48	0.60	-0.07	0.88
Science and mathematics teachers' support	700	1	6	4.08	0.88	-0.07	-0.25
Interactive science and mathematics lessons	700	1	4	2.84	0.54	-0.11	-0.23

In a similar trend with Observation 1, the students rated lower than average on performance in science and mathematics subjects (*M* = 2.50*, SD* = .77). On the other hand, they tended to rate from a moderate to high level on their science and mathematics self-efficacy (*M* = 3.08*, SD* = .65) and science and mathematics outcome expectation (*M* = 3.88*, SD* = .58).

Next is the trend of sub-constructs of attitudes towards science in Observation 2. The most noticeable attitudes constructs that the students had higher positive attitudes towards were the importance of science in society (*M*=3.90, *SD*=.57), followed by science as a practical subject (*M*=3.61, *SD*=.69), science activities outside school (*M*=3.54, *SD*=.67), and interest in science activities at school (*M*=3.41, *SD*=.67). However, the variables which Cambodian students exhibited lower attitudes towards were science and mathematics self-concepts (*M*=2.89, *SD*=.66) and extracurricular activities in science (*M*=2.74, *SD*=.78). Overall, the trend of Cambodian students' attitudes towards science is interesting. While most students tended to believe that science plays a very important role in society and that they are more likely to be interested in the practical work of science and science activities outside school, they seemed to have lower self-concepts in science and science learning which, as a result, influenced their extracurricular activities in science. This trends of the attitudes towards science sub-constructs in Observation 2 were similar to those in Observation 1. (See Figure 6.2).

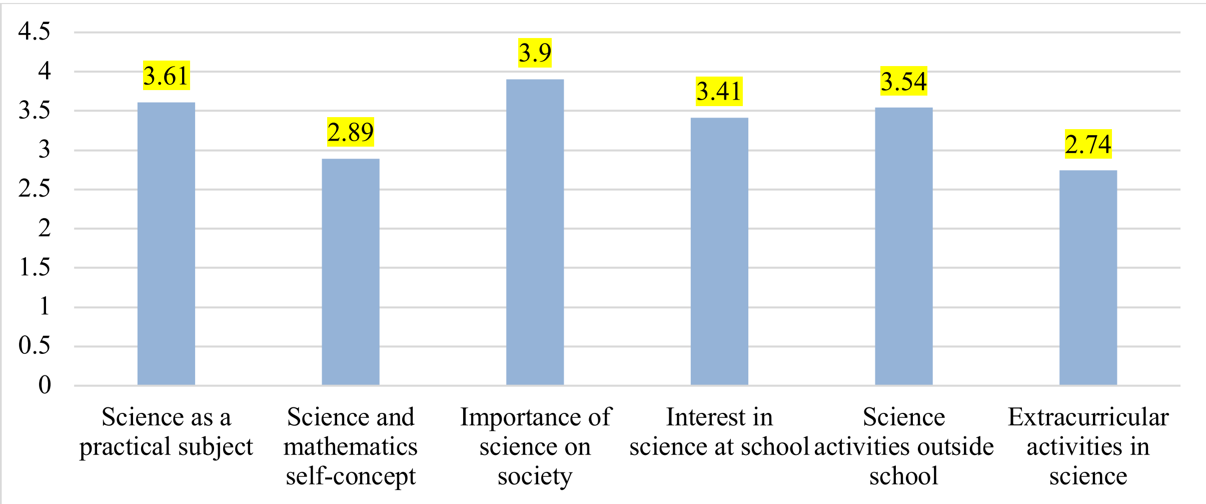


Figure 6.2: Mean of each construct of attitudes towards science in Observation 2

On the measure of future plan in science, quite similar to the trend in Observation 1, in Observation 2, the students still rated at a moderate level for future plan in science *(M*=3.20*, SD*=.70*)*. Only about 10% of the students agreed and strongly agreed to be involved more in science after finishing upper secondary schools.

6.3.2 Patterns of time-varying covariates: Observation 2

This section examines whether the above discussed time-varying covariates measured in Observation 2, were differentiated by the three demographic attributes of gender, school location, and study track.

6.3.2.1 Patterns across gender

Table 6.9 depicts the patterns of time-varying covariates in Observation 2 across gender. Interestingly, while in Observation 1, male and female students did not show any significant influence on the constructs measured, in Observation 2, male students scored significantly higher than their female counterparts on science and mathematics self-concepts, the importance of science in society, science activities outside school, and extracurricular activities in science. Based on *Cohen's d*, the strongest effects were on the constructs of extracurricular activities in science followed by science and mathematics self-concepts.

Table 6.9: Time-varying covariates by gender

Constructs	Gender	Mean	SD	*t*	Sig.	ES
Performance in science and mathematics	Male Female	2.51 2.49	.81 .75	.23	.82	--
Science and mathematics self-efficacy	Male Female	3.12 3.03	.66 .63	1.69	.09	--
Science and mathematics outcome expectations	Male Female	3.91 3.85	.57 .59	1.28	.20	--
Science as a practical subject	Male Female	3.63 3.60	.72 .67	.65	.52	--
Science and mathematics self-concept	Male Female	2.96 2.83	.68 .63	2.68	.008**	.20
Importance of science in society	Male Female	3.95 3.85	.58 .55	2.45	.01*	.19
Interest in science at school	Male Female	3.40 3.42	.68 .66	-.41	.69	--
Science activities outside school	Male Female	3.60 3.50	.71 .65	1.94	.05*	.15
Extracurricular activities in science	Male Female	2.86 2.65	.77 .78	3.57	.000***	.27
Future plan in science	Male Female	3.51 3.43	.83 .83	.83	.41	--
Family encouragement and support	Male Female	3.50 3.47	.61 .59	.77	.44	--
Science and mathematics teachers' support	Male Female	4.10 4.06	.87 .89	.70	.49	--
Interactive science and mathematics lessons	Male Female	2.89 2.81	.55 .54	1.76	.07	--

Note: - ES= *Cohen's d Effect Size*

- * when p < .05; ** when p < .01; *** when p < .001

6.3.2.2 Patterns across school location

Table 6.10: Patterns of time-varying covariates by school location

Constructs	Location	Mean	SD	*F*	Sig.	Eta^2
Performance in science and mathematics	PP	2.55	.79	6.27	.002**	.02
	KC	2.69	.79			
	BTB	2.32	.71			
Science and mathematics self-efficacy	PP	3.02	.68	11.41	.000***	.03
	KC	3.26	.58			
	BTB	2.96	.62			
Science and mathematics outcome expectations	PP	3.82	.60	5.10	.006**	.01
	KC	3.99	.51			
	BTB	3.85	.62			
Science as a practical subject	PP	3.62	.74	4.72	.009**	.01
	KC	3.71	.58			
	BTB	3.49	.71			
Science and mathematics self-concept	PP	2.84	.68	5.25	.005**	.02
	KC	3.02	.56			
	BTB	2.85	.70			
Importance of science in society	PP	3.88	.59	1.16	.313	.00
	KC	3.95	.52			
	BTB	3.87	.58			
Interest in science at school	PP	3.36	.67	5.25	.005**	.02
	KC	3.54	.57			
	BTB	3.34	.76			
Science activities outside school	PP	3.49	.71	4.19	.016*	.01
	KC	3.66	.57			
	BTB	3.51	.69			
Extracurricular activities in science	PP	2.92	.83	19.36	.000***	.05
	KC	2.65	.71			
	BTB	2.49	.67			
Future plan in science	PP	3.08	.68	12.11	.000***	.03
	KC	3.39	.70			
	BTB	3.20	.70			
Family encouragement and support	PP	3.43	.62	2.79	.062	.00
	KC	3.55	.57			
	BTB	3.51	.59			
Science and mathematics teachers' support	PP	3.86	.88	25.58	.000***	.07
	KC	4.40	.72			
	BTB	4.15	.92			
Interactive science and mathematics lessons	PP	2.74	.57	13.80	.000***	.09
	KC	3.00	.49			
	BTB	2.85	.50			

Note: - PP=Phnom Penh; KC=Kampong Cham; BTB=Battambang, Eta^2 = *Partial Eta-squared*

- * when $p < .05$; ** when $p < .01$; *** when $p < .001$

Table 6.10 demonstrates whether the time-varying covariates in Observation 2 were differentiated by the location of the schools. One-way ANOVA also revealed that the three provinces exhibited significant influence on the constructs measured, except for the importance of science in society and family encouragement and support to pursue science. Interestingly, this effect did not vary much from observations 1 to 2. The only change was that the difference in school location neutralized its effects on science and mathematics outcome expectations.

Table 6.11: Post-hoc Tukey HSD test on the differences in school location on the constructs

Constructs	**Location (I)**	**Location (J)**	**I-J**	**Sig.**
Performance in science and mathematics	PP	KC	-0.4	.803
		BTB	.22	.007**
	KC	BTB	.26	.004**
Science and mathematics self-efficacy	PP	KC	-.23	.000***
		BTB	.07	.506
	KC	BTB	.29	.000***
Science and mathematics outcome expectations	PP	KC	-.16	.005**
		BTB	-.02	.893
	KC	BTB	.14	.057
Science as a practical subject	PP	KC	-.09	.355
		BTB	.13	.097
	KC	BTB	.22	.007**
Science and mathematics self-concept	PP	KC	-.18	.006**
		BTB	-.01	.975
	KC	BTB	.17	.035*
Interest in science at school	PP	KC	-.17	.013*
		BTB	.03	.907
	KC	BTB	.20	.013*
Science activities outside school	PP	KC	-.17	.014*
		BTB	-.03	.905
	KC	BTB	.14	.098
Extracurricular activities in science	PP	KC	.26	.000***
		BTB	.42	.000***
	KC	BTB	.16	.115
Future plan in science	PP	KC	-.31	.000***
		BTB	-.12	.172
	KC	BTB	.19	.022*
Science and mathematics teachers' support	PP	KC	-.54	.000***
		BTB	-.29	.001**
	KC	BTB	.25	.013*
Interactive science and mathematics lessons	PP	KC	-.25	.000***
		BTB	-.10	.097
	KC	BTB	.15	.020*

Note: * when p < .05; ** when p < .01; *** when p < .001

As indicated in Table 6.11, Post-hoc Tukey HSD test was conducted to investigate the differences in school location on the constructs. Overall, it is interesting to note that schools in Phnom Penh have significantly lower performance than those in Kampong Cham Province on the constructs of science and mathematics self-efficacy, science and mathematics outcome expectations, science and mathematics self-concepts, interest in science at school, science activities outside school, future plan in science, science and mathematics teachers' support, and interactive science and mathematics lessons, but higher performance on extracurricular activities in science. This was in contrast with what was found in the first observation, where schools in Phnom Penh tended to have higher performance. Second, schools in Phnom Penh performed significantly better than those in Battambang Province, but only on performance in science and mathematics and extracurricular activities in science, and lower on science and mathematics teachers' support. Third, schools located in Kampong Cham had significantly higher scores than their counterparts in Battambang Province on most constructs, except for science and mathematics outcome expectations, science activities outside school, and extracurricular activities in science.

6.3.2.3 Patterns across study tracks

Third, Table 6.12 indicates the effects of choosing different tracks (the science track at traditional schools, the science track at NGS, and the social science track) on time-varying covariates in Observation 2. Similar to what was discovered in the first observation, most of the constructs were significantly differentiated by which track the students attended, except for science and mathematics teachers' support. Overall, the science track in NGS had the highest score, followed by the science track in traditional upper secondary schools and, as hypothesized, the social science track all had $p < .001$. Based on the value of *partial eta-squared*, performance in science and mathematics, science as a practical subject, interest in science activities at school, and science and mathematics self-efficacy had greater effect size among the other constructs. Although the effect sizes (η_p^2) for most of the constructs ranged from 0.05 to 0.22 (which indicated a small to large effect), the effect size for interactive science and mathematics lessons was small in scale ($eta^2 = 0.02$). This indicated that despite a significant difference between different tracks on the level of interactive science and mathematics lessons, in practical terms the effect was small. The effect size was lower in the second observation than in the first observation.

Table 6.12: Patterns of time-varying covariates by track

Constructs	Track	Mean	SD	*F*	Sig.	Eta^2
Performance in science and mathematics	NGS	2.98	.80	100.59	.000***	.22
	Science	2.65	.69			
	Social	2.05	.58			
Science and mathematics self-efficacy	NGS	3.37	.54	86.30	.000***	.20
	Science	3.24	.60			
	Social	2.70	.57			
Science and mathematics outcome expectations	NGS	3.96	.55	20.29	.000***	.06
	Science	3.99	.52			
	Social	3.70	.62			
Science as a practical subject	NGS	4.02	.51	96.51	.000***	.22
	Science	3.75	.57			
	Social	3.21	.71			
Science and mathematics self-concept	NGS	3.10	.61	63.53	.000***	.15
	Science	3.07	.63			
	Social	2.54	.57			
Importance of science in society	NGS	4.16	.54	38.02	.000***	.10
	Science	3.93	.50			
	Social	3.69	.58			
Interest in science at school	NGS	3.66	.55	96.33	.000***	.22
	Science	3.64	.59			
	Social	2.99	.62			
Science activities outside school	NGS	3.67	.62	17.98	.000***	.05
	Science	3.64	.62			
	Social	3.34	.72			
Extracurricular activities in science	NGS	3.39	.67	90.12	.000***	.21
	Science	2.65	.73			
	Social	2.46	.67			
Future plan in science	NGS	3.33	.66	51.10	.000***	.13
	Science	3.14	.63			
	Social	2.86	.68			
Family encouragement and support	NGS	3.78	.57	52.12	.000***	.13
	Science	3.56	.52			
	Social	3.22	.59			
Science and mathematics teachers' support	NGS	4.15	.81	2.95	.052	.00
	Science	4.13	.83			
	Social	3.97	.95			
Interactive science and mathematics lessons	NGS	2.99	.49	8.62	.000***	.02
	Science	2.85	.52			
	Social	2.76	.58			

Note: - Eta^2 = *Partial Eta-squared*

- *** when $p < .001$

Post-hoc Tukey HSD test was conducted to investigate the differences in study track on the constructs. Overall, the multiple comparison for the Observation 2 data revealed a similar trend to the multiple comparison for the Observation 1 data. Therefore, for the matter of space, the Post-hoc Tukey HSD table regarding the effects of the three different tracks of science in NGS, the science track, and the social science track in traditional upper secondary schools was not presented here.

6.4 Trends and patterns across the two observations

6.4.1 Trends across observations

Table 6.13 shows if the time-varying covariates increased or decreased from observations 1 to 2. Paired sample t-test was conducted. The result indicated that, for most of the constructs, there was a statistically significant increase from observations 1 to 2, except for future plan in science and science and mathematics teachers' support. Simply explain, there was a significant increase in students' performance in science and mathematics, $t(699) = -6.71$, $p = .000$, $d = .25$; science and mathematics self-efficacy, $t(699) = -3.40$, $p = .001$, $d = .13$; science and mathematics self-concepts, $t(699) = -4.44$, $p = .000$, $d = .17$; the importance of science in society, $t(699) = -3.67$, $p = .000$, $d = .14$; interest in science at school, $t(699)= -2.56$, $p = .011$, $d = .09$; science activities outside school, $t(699) = -2.58$, $p = .01$, $d = .14$; extracurricular activities in science, $t(699) = -7.38$, $p = .000$, $d = .27$; and family encouragement and support, $t(699) = -4.53$, $p = .000$, $d = .18$. However, there was a significant decrease in future plan in science, $t(699) = 4.14$, $p =.000$, $d = .18$; and science and mathematics teachers' support, $t(699) = -2.41$, $p = .016$, $d = .09$. In short, although there was a significant increase in some constructs, the effect was not significant, even in negative trends in some other constructs.

Table 6.13: Trends of time-varying covariates across the observations

Constructs	n	Observation 1		Observation 2		*t*	*p*	ES
		M	***SD***	***M***	***SD***			
Performance in science and mathematics	700	2.36	.85	2.50	.77	-6.71	.000***	.25
Science and mathematics self-efficacy	700	3.01	.67	3.08	.65	-3.40	.001**	.13
Science and mathematics outcome expectations	700	3.85	.63	3.88	.58	-1.09	.278	.04
Science as a practical subject	700	3.57	.76	3.61	.69	-1.90	.059	.07
Science and mathematics self-concept	700	2.79	.71	2.89	.66	-4.44	.000***	.17
Importance of science in society	700	3.81	.63	3.89	.57	-3.67	.000***	.14
Interest in science at school	700	3.34	.77	3.41	.67	-2.56	.011*	.09
Science activities outside school	700	3.47	.67	3.54	.67	-2.58	.010*	.10
Extracurricular activities in science	700	2.51	.76	2.74	.78	-7.38	.000***	.27
Future plan in science	700	3.33	1.01	3.20	.70	4.14	.000***	.16
Family encouragement and support	700	3.38	.67	3.48	.60	-4.53	.000***	.18
Science and mathematics teachers' support	700	4.16	.87	4.07	.88	2.41	.016*	.09
Interactive science and mathematics lessons	700	2.85	52	2.84	.54	.10	.923	.00

Note: - ES = *Cohens' d Effect Size*
- * when p < .05; ** when p < .01; *** when p < .001

6.4.2 Patterns across observations and gender

A 2 (observation) x 2 (gender) repeated ANOVA was conducted to observe the patterns of time-varying covariates across the two observations and gender, see Table 6.14. First, the main effect for observation was significant for most constructs, except for science and mathematics outcome expectations and interactive science and mathematics lessons. Thus, there was a difference in the other constructs for Observation 1 compared to Observation 2. However, the effect size was small (the *eta-squared* ranged from .01 to .08). More interestingly, a significant observations x gender was also obtained. Quite opposite to the main effect, the interaction effect between observation and gender was not significant for most constructs, except for science and mathematics self-efficacy, science and mathematics self-concepts, and extracurricular activities in science. The effect size was small.

Investigation of the estimated marginal mean indicated that in the first observation, males and females scored the same on science and mathematics self-efficacy. Notwithstanding, in Observation 2, males increased their science and mathematics self-efficacy more than females. This indicates that males tended to increase the constructs at a higher rate than females. Second, for science and mathematics self-concepts, there was an increasing trend for both males and females from observations 1 to 2. Yet, it is significant to note that the trend was much larger for males than for females. Males and females scored nearly the same in Observation 1, but the gap was extended in Observation 2. Third, for extracurricular activities in science, males and females had the same low mean score in Observation 1. However, there was an increasing trend in Observation 2, with males being more involved in the activities in Observation 2 than their female counterparts. In short, within these three constructs, there was increasing trends from observations 1 to 2, with males having higher scores than female students.

Table 6.14: Trends of time-varying covariates as a function of observation and gender

Constructs	***Source***	***Df***	***MS***	***F***	***p***	**Eta²**
Performance in science and mathematics	Observation	1	7.26	45.59	.000***	.06
	Obs.*Gender	2, 697	.09	.59	.443	.00
Science and mathematics self-efficacy	Observation	1	1.86	13.08	.000***	.02
	Obs.*Gender	2, 697	.57	4.02	.045*	.00

Science and mathematics outcome expectations	Observation	1	.32	1.58	.210	.00
	Obs.*Gender	2, 697	.47	2.33	.127	.00
Science as a practical subject	Observation	1	.80	4.07	.044*	.01
	Obs.*Gender	2, 697	.27	1.38	.241	.00
Science and mathematics self-concept	Observation	1	3.95	21.92	.000***	.03
	Obs.*Gender	2, 697	.94	5.22	.023*	.01
Importance of science in society	Observation	1	2.82	14.69	.000***	.02
	Obs.*Gender	2, 697	.47	2.47	.117	.00
Interest in science at school	Observation	1	1.71	7.38	.008**	.01
	Obs.*Gender	2, 697	.55	2.36	.125	00
Science activities outside school	Observation	1	1.73	7.06	.008**	.01
	Obs.*Gender	2, 697	.17	.69	.407	.00
Extracurricular activities in science	Observation	1	20.74	59.84	.000***	.08
	Obs.*Gender	2, 697	3.46	9.99	.002**	.01
Future plan in science	Observation	1	5.88	15.31	.000***	.02
	Obs.*Gender	2, 697	1.24	3.23	.073	.01
Family encouragement and support	Observation	1	4.15	21.57	.000***	.03
	Obs.*Gender	2, 697	.31	1.60	.208	.00
Science and mathematics teachers' support	Observation	1	1.85	4.93	.027*	.01
	Obs.*Gender	2, 697	.97	2.58	.109	.00
Interactive science and mathematics lessons	Observation	1	.00	.01	.916	.00
	Obs.*Gender	2, 697	.51	3.14	.077	.00

Note: Obs. = Observation; * when $p < .05$; ** when $p < .01$; *** when $p < .001$

6.4.3 Patterns across observations and school locations

A 2 (observation) x 3 (school location) repeated ANOVA was also conducted to observe the patterns of time-varying covariates across the two observations and school locations (see Table 6.15 for details). The main effect for observation was significant for most constructs, except for science and mathematics outcome expectations, science and mathematics teachers' support, and interactive science and mathematics lessons. Thus, there was a difference in the other constructs for Observation 1 compared to Observation 2. However, the effect size was small (the eta^2 ranged from .01 to .08). By contrast, a significant interaction between observation x location was also obtained. Unlike the main effect, the interaction effect between observation and location was not significant for most constructs, except for science and mathematics self-efficacy, science and mathematics self-concepts, and extracurricular activities in science. The effect size was small.

Table 6.15: Patterns of time-varying covariates as a function of observation and school location

Constructs	***Source***	***Df***	***MS***	***F***	***p***	**Eta^2**
Performance in science and mathematics	Observation	1	8.05	50.96	.000***	.07
	Obs.*Loc.	2, 697	.57	3.62	.027*	.01
Science and mathematics self-efficacy	Observation	1	2.06	14.53	.000***	.02
	Obs.*Loc.	2, 697	.38	2.69	.068	.00
Science and mathematics outcome expectations	Observation	1	.50	2.46	.117	.00
	Obs.*Loc.	2, 697	.38	1.89	.152	.00
Science as a practical subject	Observation	1	1.22	6.21	.013*	.01
	Obs.*Loc.	2, 697	.60	3.05	.048*	.01
Science and mathematics self-concept	Observation	1	3.95	21.82	.000***	.03
	Obs.*Loc.	2, 697	.22	1.23	.292	.00
Importance of science in society	Observation	1	2.80	14.52	.000***	.02
	Obs.*Loc.	2, 697	.10	.54	.582	.00
Interest in science at school	Observation	1	1.90	8.17	.004**	.01
	Obs.*Loc.	2, 697	.26	1.12	.326	.00
Science activities outside school	Observation	1	1.86	7.58	.006**	.01
	Obs.*Loc.	2, 697	.13	.53	.589	.00
Extracurricular activities in science	Observation	1	16.11	45.89	.000***	.06
	Obs.*Loc.	2, 697	.32	.91	.405	.00
Future plan in science	Observation	1	3.75	9.91	.002**	.01
	Obs.*Loc.	2, 697	2.75	7.27	.001**	.02
Family encouragement and support	Observation	1	4.28	22.30	.000***	.03
	Obs.*Loc.	2, 697	.32	1.65	.195	.00
Science and mathematics teachers' support	Observation	1	1.33	3.54	.060	.00
	Obs.*Loc.	2, 697	.58	1.55	.213	.00
Interactive science and mathematics lessons	Observation	1	.01	.09	.770	.00
	Obs.*Loc.	2, 697	.36	2.19	.113	.00

Note: Obs. = Observation; Loc. = Location; * when p < .05; ** when p < .01; *** when p < .001

6.4.4 Patterns across observations and study tracks

Table 6.16: Trends of time-varying covariates as a function of observation and study track

Constructs	*Source*	*Df*	*MS*	*F*	*p*	Eta^2
Performance in science and mathematics	Observation	1	4.36	28.42	.000***	.04
	Obs.*Track	2, 697	2.11	13.74	.000***	.04
Science and mathematics self-efficacy	Observation	1	1.82	12.96	.000***	.02
	Obs.*Track	2, 697	.77	5.50	.004**	.02
Science and mathematics outcome expectation	Observation	1	.19	.95	.331	.00
	Obs.*Track	2, 697	.18	.88	.415	.00
Science as a practical subject	Observation	1	.52	2.69	.101	.00
	Obs.*Track	2, 697	1.35	6.93	.001**	.02
Science and mathematics self-concept	Observation	1	3.20	17.92	.000***	.03
	Obs.*Track	2, 697	1.00	5.58	.004**	.02
Importance of science in society	Observation	1	2.97	15.45	.000***	.02
	Obs.*Track	2, 697	.23	1.21	.300	.00
Interest in science at school	Observation	1	1.65	7.17	.008**	.01
	Obs.*Track	2, 697	.88	3.80	.023*	.01
Science activities outside school	Observation	1	1.61	6.55	.011*	.01
	Obs.*Track	2, 697	.13	.51	.599	.00
Extracurricular activities in science	Observation	1	23.92	69.89	.000***	.10
	Obs.*Track	2, 697	3.39	9.90	.000***	.03
Future plan in science	Observation	1	8.06	22.76	.000***	.03
	Obs.*Track	2, 697	11.26	31.78	.000***	.08
Family encouragement and support	Observation	1	3.86	20.32	.000***	.03
	Obs.*Track	2, 697	1.05	5.51	.004**	.02
Science and mathematics teachers' support	Observation	1	3.26	8.75	.003**	.01
	Obs.*Track	2, 697	1.60	4.29	.014*	.01
Interactive science and mathematics lessons	Observation	1	.01	.08	.775	.00
	Obs.*Track	2, 697	.06	.35	.706	.00

Note: Obs. = Observation; * when $p < 0.05$; ** when $p < .01$; *** when $p < .001$

A 2 (observations) x 3 (study tracks) repeated ANOVA was conducted to observe the patterns of the time-varying covariates (see Table 6.16 for details). First, it was revealed that the main effect for observation was significant, $F(1,697) = 28.42$, $p < .001$, Eta-squared = .04. Thus, there was a difference in *performance in science and mathematics* for Observation 1 (*M* = 2.36) compared to Observation 2 (*M* = 2.50). There was a small effect (Eta-squared = .04). However, a significant observation x study track was also obtained, $F(1,697) = 13.74$, $p < .001$; the effect was small (Eta-squared = .04). Examination of the cell means indicated that there was a small increase in performance in the science and mathematics score. In Observation 1, NGS students had higher performance (*M* = 3.04) than students in the science track (*M* = 2.50), and the social science track (*M* = 1.81). Notwithstanding, in Observation 2, the performance in science and mathematics subjects of the NGS decreased (*M* = 2.98), yet it was still higher than that of students in the science track (*M* = 2.65), and the social science track (*M* = 2.05).

Second, for *science and mathematics self-efficacy*, the main effect for observations was significant, $F(1,697) = 12.96$, $p < .001$, $\text{Eta}^2 = .02$. Hence, there was a difference in science and mathematics self-efficacy for Observation 1 (*M* = 3.01) compared to Observation 2 (*M* = 3.08), with a weak effect ($\text{Eta}^2 = .02$). Moreover, a significant observation x study track was also obtained, $F(1,697) = 5.50$, $p < .01$; the effect was weak ($\text{Eta}^2 = .02$). Examination of the cell means indicated a very small increase in science and mathematics self-efficacy. In Observation 1, NGS students had higher self-efficacy (*M* = 3.28) than students in the science track (*M* = 3.25), and the social science track (*M* = 2.55). Interestingly, in Observation 2, the science and mathematics self-efficacy of the NGS increased slightly (*M* = 3.37) and was higher than that of students in the science track (*M* = 3.25), and the social science track (*M* = 2.70).

Third, the main effect of *science as a practical subject* was not significant. However, a significant observation x study track was also obtained, $F(1,697) = 6.93$, $p < .01$; the effect was weak ($\text{Eta}^2 = .02$). Moreover, examination of the cell means indicated that there was a very small decrease in the practicality of science subjects. In Observation 1, the NGS students had higher attitudes towards the practicality of science (*M* = 4.04) than students in the science track (*M* = 3.78), and the social science track (*M* = 3.04). However, in Observation 2, the perceived practicality in science subjects of the NGS students fell slightly (*M* = 4.00), but it was still higher than that of student in the science track (*M* = 3.75), and the social science track (*M* = 3.21).

Next, there was a main effect of observation on *science and mathematics self-concept* $F(1,697) = 17.92$, $p < .001$, $\text{Eta}^2 = .03$ and the interaction effect between observation and study track, $F(1,697) = 5.58$, $p < .01$, $Eta^2 = .02$. In Observation 1 NGS students had the same level of science and mathematics self-concepts ($M = 3.04$) as students in the science track ($M = 3.04$), but higher than students in the social science track ($M = 2.35$). However, in Observation 2, the science and mathematics self-concepts of the NGS slightly increased ($M = 3.10$). Thus, it was higher than that of students in the science track ($M = 3.07$), and the social science track ($M = 2.55$).

For the *importance of science in society*, there was only the main effect of the observations, $F(1,697) = 15.45$, $p < .001$, $Eta^2 = .02$, but there was no significant interaction effects between observations and study tracks on the perceived importance of science in society, $F(1,697) = 1.21$, $p > .05$. This was also the case for science activities outside school. The main effect of observations on science activities outside school was significant, $F(1,697) = 6.55$, $p < .05$, $Eta^2 = .01$, but there was no interaction effect between the observations and study tracks.

Furthermore, for *interest in science at school*, the main effect for observation was significant $F(1,697) = 7.17$, $p < .01$, $Eta^2 = .01$. Thus, there was a difference in interest in science at school for Observation 1 ($M = 3.34$) as compared to Observation 2 ($M = 3.41$). There was a weak effect ($Eta^2 = .01$). Moreover, a significant observation x study track was also obtained, $F(1,697) = 3.80$, $p < .05$, although there was a weak effect ($Eta^2 = .01$). Examination of the cell means indicated that there was a very small increase in interest in science at school. In Observation 1, NGS students had lower interest ($M = 3.58$) than students in the science track ($M = 3.65$), but higher than in the social science track ($M = 2.85$). However, in Observation 2, interest in science at school among students in the NGS slightly increased ($M = 3.66$) to be higher than that of students in the science track ($M = 3.64$), and the social science track ($M = 2.99$).

The main effect of *extracurricular activities in science* was significant, $F(1,697) = 69.89$, $p < .001$, $Eta^2 = .01$. Thus, there was a difference in extracurricular activities in science for Observation 1 ($M = 2.51$) compared to Observation 2 ($M = 2.74$), but the effects were small. Furthermore, a significant observation x study track was also obtained, $F(1,697) = 9.90$, $p < .001$; the effect was weak ($Eta^2 = .03$). Examination of the cell means indicated that there was an increase in extracurricular activities in science. In Observation 1, the NGS students had higher extracurricular activities in science ($M = 2.90$) than students in the science track ($M = 2.48$), and the social science track ($M = 2.31$). Interestingly, in Observation 2, the level of extracurricular activities in science of the NGS increased to (M = 3.39) higher than that of student in the science track (M = 2.65), and the social science track (M = 2.46).

It is surprising to note that the main effect of *future plan in science* was significant, $F(1,697) = 22.76$, $p < .001$, $\text{Eta}^2 = .03$. Thus, there was a difference in students' future plan in science for Observation 1 (M = 3.33) compared to Observation 2 (M = 3.19). Furthermore, a significant observation x study track was also obtained, $F(1,697) = 31.78$, $p < .001$, with a medium effect ($\text{Eta}^2 = .08$). Examination of the cell means pointed to a decrease in future plan in science as the students moved on to higher grades. In Observation 1, NGS students had lower future plan in science (M = 3.69) than the students in the science track (M = 3.73), but higher than students in the social science track (M = 2.67). In a worrisome trend, in Observation 2, the students' future plan in science at the NGS decreased to M = 3.33, and continued to be lower compared to students in the science track (M = 3.41), but higher than students in the social science track (M = 2.87).

For the contextual support constructs, the main effect of *family encouragement and support* was significant, but with a very small effect, $F(1,697) = 20.32$, $p < .001$, $\text{Eta}^2 = .03$. Thus, there was a difference in family encouragement and support for Observation 1 (M = 3.37) compared to Observation 2 (M = 3.48). Furthermore, a significant observation x study track was also obtained, $F(1,697) = 5.51$, $p < .01$, with a small effect ($\text{Eta}^2 = .02$). Examination of the cell means revealed an increase in family encouragement and support as students moved on to higher grades. In Observation 1, NGS students had higher family encouragement and support (M = 3.68) than students in the science track (M = 3.53), and the social science track (M = 3.02). In Observation 2, the family encouragement and support of the NGS students increased to (M = 3.78) and continued to be higher compared to students in the science track (M = 3.60), and the social science track (M = 3.22).

Lastly, for another contextual support construct, the main effect of *science and mathematics teachers' support* was also significant, $F(1,697) = 8.75$, $p < .01$, $\text{Eta}^2 = .01$. Thus, there was a difference in science and mathematics teachers' support for Observation 1 (M = 4.15) compared to Observation 2 (M = 4.07). Furthermore, a significant observation x study track was also witnessed, $F(1,697) = 4.29$, $p < .05$, but with a small effect ($\text{Eta}^2 = .01$). Examination of the cell means indicated a decrease in science and mathematics teachers' support as the students moved on to higher grades. In Observation 1 NGS students had higher science and mathematics teachers' support (*M* = 4.39) than students in the science track (*M* = 4.22), and the social science track (*M* = 3.95). In Observation 2 the science and mathematics teachers' support among the NGS students decreased to (*M* = 4.15), and continued to be just the same as students in the science track (*M* = 4.13), but higher than student in the social science track (*M* = 3.97).

6.5 Discussion of key themes for RQ 2

6.5.1 Trends of time-varying covariates

According to the trends witnessed in the time-varying covariates, in Observation 1, Cambodian upper secondary school students rated science and mathematics outcome expectations, science as a practical subject, and the importance of science in society at a high level. However, they rated science and mathematics self-efficacy, science and mathematics self-concepts, interest in science at school, science activities outside school, extracurricular activities in science, future plan in science, support from science and mathematics teachers and interactive science and mathematics lessons at a moderate level. They rated their performance in science and mathematics at a low level. For Observation 2, the students exhibited a low to moderate level of performance in science and mathematics, science and mathematics self-efficacy and outcome expectations, attitudes towards science sub-constructs (an uneven trend among the sub-construct), future plan in science, family encouragement and support, science and mathematics teachers' support, and the interactive science and mathematics lessons.

There are a few interesting trends to be noted. Emerging findings are reflected with respect to the realities of Cambodian upper secondary school students' performance in science and mathematics. The students tended to state that they have low performance in science and mathematics. This finding is consistent with a recent study, which revealed that on the 2015 national examination, out of 83,325 students, only 23.3% passed the mathematics portion, while 41.7% passed the biology portion (Chey & Khieu, 2017). Moreover, according to the outcomes of the Programme for International Student Assessment for Development (PISA-D), Cambodian 15-year-old (grade 11th) students outperformed those in Senegal and Zambia in all subjects and obtained academic performance in mathematics comparable to those in other PISA-D member states (Cambodia scored 325, while the PISA-D average was 324). However, they had significantly lower performance in science than those in PISA-D and

ASEAN countries (Vietnam, Thailand, Indonesia, and Singapore). Their performance was especially lower than students in OECD member nations. Cambodian students scored 330 in science out of roughly 700. On average, students in PISA-D member countries scored 349 in science (MoEYS, 2018g). The result of the follow-up interviews confirmed that students did not like to struggle with science and mathematics at upper secondary school, especially on the baccalaureate examination. As a result, most students have tended to choose the social science track (for which they do not need to do science and mathematics) rather than the social science track in the last few academic years (MoEYS, 2019c).

On another note, there is an uneven trend of attitudes towards the science sub-constructs. With the current development of science and technology, of all other instances, the students displayed a higher level of awareness of science and technology, particularly regarding the importance of science in society. This is a very interesting sign, since according to Cambodia's national science and technology master plan for 2014–2020 of the Royal Government of Cambodia (RGC, 2013), Cambodia only had 17 science and technology researchers and 13 technicians per million of its population, due to the fact that Cambodia's social awareness of science and technology is generally low in the country. However, the results of the present study indicated a different trend of students' awareness of science and technology in general, and the importance of science in society in particular.

Students showed more positive attitudes towards the practical work of science subjects. According to Marginson et al. (2013), Freedman (1997), and Papanastasiou and Papanastasiou (2004), the teaching methods of problem-solving, inquiry, critical thinking, and creativity should be considered because they can enhance both students' attitudes towards and practical competency in science-related fields. In the Cambodian upper secondary school context, practical work—especially in science classes—is of concern (CDRI, 2015). However, with the current improvements of MoEYS, this teaching practice has been improving. For instance, from 2000 to 2005, JICA launched several projects. These included the Secondary School Teacher Training Project in Science and Mathematics (STEPSAM), to reinforce the science and mathematics teaching functions and capabilities of the country's National Institute of Education (NIE), which trains high school teachers; the Project for Improving Science and Mathematics Education at the Upper Secondary Level (ISMEC), implemented from 2005 to 2008; and STEPSAM II, which was carried out from 2008 to 2012 (Center for Research and Development Strategy, 2015); the Flemish Association for

Development Cooperation and Technical Assistance (VVOB) to improve mathematics and science teaching methods at the classroom level; and other projects (Secondary Education Improvement Project [SEIP]) from other development partners. This might have influenced the improvement of science and mathematics education in Cambodia and boosted students' attitudes towards practical work in science in the long run.

In the other continuum, the results also revealed the emerging trend of Cambodian students' self-interest in science activities outside school, which included science movies on TV, reading science magazines, and other science activities. Besides these self-interest activities, students also exhibited a moderate level of attitudes towards extracurricular activities in science. Some students that participated in the survey have experienced the so-called STEM bus and STEM festival, which are meant to enhance their attitudes towards science subjects at upper secondary school. In existence now for a few years, the STEM bus (modelled from Lab in a Lorry in the British context), travels to upper secondary schools across the country to exhibit science expos as well as to promote awareness of and interest in STEM majors in secondary schools (MoEYS, 2018d). Empirically, Barmby et al. (2008) and Forsthuber, Motiejunaite, and de Almeida Coutinho (2011), reported that Lab in a Lorry has been significantly contributing to building students' interest in and attitudes towards the practical work of science and science learning in school. In this regard, in the same vein of implementation as Lab in a Lorry, the STEM Bus in the Cambodian context might have also contributed to enhancing students' interest in and attitudes towards science in general, and attitudes towards extracurricular activities in science in particular.

Students exhibited moderate level of attitudes towards the self-concepts of science and mathematics might be due to the fact that science is perceived as a difficult subject. There is an interesting reflection in this finding. In the past years, at the upper secondary school about 80% of the students have taken science classes (MoEYS, 2017; 2018a). This might be because students believed that science was difficult, especially in terms of passing the national examination; together with the lower self-concepts in science and mathematics, their future plan in science were low, and even lower in the second observation. The qualitative results confirmed that science is difficult, especially during the examination. As evidence, MoEYS (2019c) reported that the number of students in the science track at upper secondary school keep decreasing. The percentage has fallen from about 80% to 49% in the last few academic years.

6.5.2 Gender perspective

From a gender perspective, in the first observation, there was no significant difference between males and females on all of the constructs measured. However, in the second observation, there was a difference between males and females for the three constructs of attitudes towards science: (1) science and mathematics self-concepts, (2) interest in science activities outside school, and (3) extracurricular activities in science, for which males seemed to have a higher scale.

The results showed divergent features of students' attitudes towards science that emerged within students' gender dynamics. Overall, adding on the findings by Crisp and Nora (2006), Francis and Greer (1999), Hodson and Freeman (1983), OECD (2016), and Simpson and Oliver (1990) this study revealed that male students seemed to have higher attitudes than female students towards science. The most advantageous aspects that male students had over females were science and mathematics self-concepts, science activities outside school, and extracurricular activities in science. The most noticeable patterns of the differences relative to gender were in extracurricular activities in science among males ($M = 2.86$, $SD = .77$), who scored significantly higher than females ($M = 2.65$, $SD = .78$), $p < .001$ with a moderate effect size of $d = .27$, followed by science and mathematics self-concepts (effect size of $d = .20$) and science activities outside school (effect size of $d = .15$). Contextually, these differences may be partly due to the cultural perceptions of Cambodian people, especially parents, that science is a male-dominant field. This finding is also supported by the empirical justifications that females have lower attitudes towards science because of their science self-conceptions and their conception of minority aspects in science classes (Handley & Morse, 1986, OECD, 2016).

In the Cambodian context, the term "science" is associated with male-dominated jobs (Mark, 2016; Kaing, 2016). Thus, female students tended to swing from science. This is particularly interesting when they move on to higher grades. To a great extent, this signals a lower interest in and attitudes towards science among female students. Moreover, because science subjects are usually perceived as difficult (CDRI, 2015), and since female students in Cambodia's upper secondary school (aged 18–22) usually spend their spare time supporting their families' daily routines (e.g., cleaning and cooking), they might not have enough time to spend on those difficult subjects at home. Eng and Szmodis (2015) highlighted that social norms require females to stay close to home and to help with household chores and care for younger siblings. This finding could also be explained by the fact that female teachers in science and mathematics have higher subjective evaluations for their female students and to encourage them more than male teachers do (Ma, 2011; Stearns et al., 2016). However, in the sampled schools, there were fewer female science and mathematics teachers than male teachers. This might have led to lower interest among female students in participating in science related activities.

In the other continuum, male students have more access to the extracurricular activities outside the home, which could reinforce their attitudes towards science, as exhibited in this current study. Hence, this might influence their science performance and attitudes towards science in the long run. The discussion during the interviews corroborated the finding, as the interviewees expresses that male students tend to have more science self-concept than female students. Males may not take the science track at the beginning, but they are more willing to major in science or STEM fields because they have higher self-concepts in science and mathematics than females in later grade (t=2.68, p<.01; d=.20).

6.5.3 School location matters

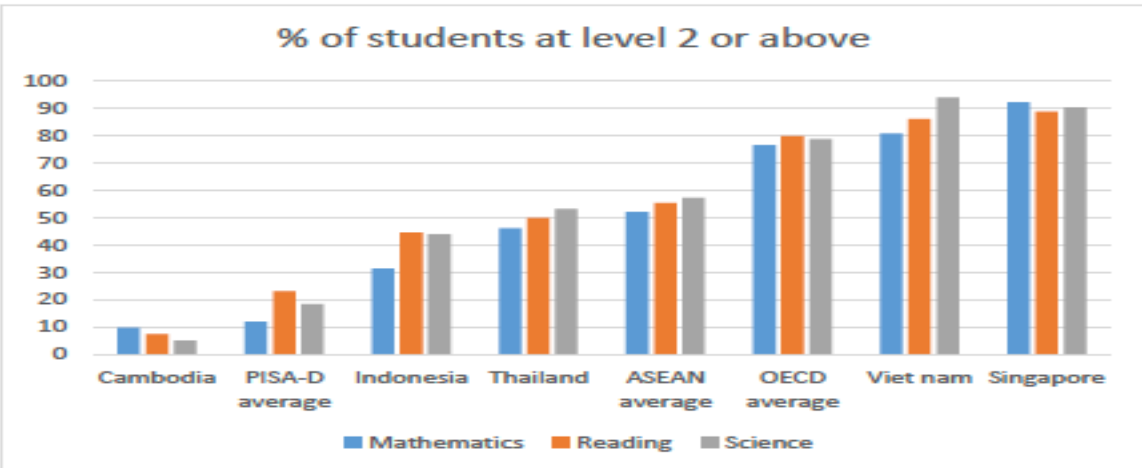
From the angle of location, the results revealed a significant difference in the level of constructs across school location. Schools in Phnom Penh had a significantly higher mean score than schools in Kampong Cham for extracurricular activities in science, but a significantly lower mean score for future plan in science, science and mathematics teachers' support, and interactive science and mathematics lessons. Moreover, schools in Phnom Penh performed better than schools in Battambang for performance in science and mathematics, science as a practical subject, and extracurricular activities in science, but lower for science and mathematics teachers' support and interactive science and mathematics lessons. From the standpoint of provinces, schools in Kampong Cham performed significantly higher than schools in Battambang for performance in science and mathematics, science and mathematics self-efficacy, science as a practical subject, science and mathematics self-concepts, interest in science activities outside school, future plan in science, and science and mathematics teachers' support in science. Similar trends could be seen in Observation 2. However, there was an increase in effect size from the first observation, particularly for science and mathematics self-efficacy, extracurricular activities in science, future plan in science, science and mathematics teachers' support, and interactive science and mathematics lessons. This phenomenon highlighted the different effects of school location/condition in enhancing the constructs under investigation.

First, there were moderate effects of different school locations on science and mathematics teachers' support in science. Science and mathematics teachers at schools in the provinces provided more support in science to students than teachers from schools in Phnom Penh. The effect size increased from the first to the second observation. This reflected the influence of science and mathematics teachers on students' interest in science. This study was consistent with other contexts, which highlighted that teachers influence how students think about their self-efficacy in the subjects, as well as change students' beliefs about the consequences of choosing science (e.g., Gaskell et al., 1993; Lindner et al., 2004; Myeong, et, al. 1991; Woolnough, 1994a). Contextually, there are a few anecdotes to explain this phenomenon. First, students in the provinces might perceive that science and mathematics majors as being more oriented towards becoming science and mathematics teachers. Since they see their science and mathematics teachers as their role models, they tended to approach their teachers for more support and advice for the school-to-work transition. The qualitative interviews confirmed this phenomenon. Remarks included, "You could approach me any time I am just your teacher." and "My teacher encouraged me to take science". Second, students in the provinces may have closer relationships with their teachers than those in Phnom Penh.

Next, schools in Kampong Cham Province tended to have higher support from science and mathematics teachers, which might be due to a few reasons. First, as mentioned earlier, science and mathematics teachers at upper secondary school in the provinces tend to provide higher support to the students. Second, there is one NGS located in this province. Based on the characteristics of the NGS, teachers should have more time to interact with the students both in and outside the classroom activities. As stated in the policy on NGS, one objective of this school is to expand educational services for Cambodian youth, including career counselling services, differentiated learning channels (e.g., project work, subject clubs), mobile learning, and life skills education (MoEYS, 2016c). With this objective, students from NGS might have more advantages than those from traditional upper secondary schools in accessing interactive sessions/time with their teachers, especially in guiding their career pursuits.

Second, we should note the different effects of school location on students' performance in science and mathematics, as well as science and mathematics self-efficacy. Although there was a low effect of school location on students' performance in science and mathematics in the first observation, the effect size declined in the second observation. This reflects the decreased effect of the variation in students' performance with respect to the school location, yet there was still significance. Detail investigation revealed that in the first observation, students from upper secondary schools in Phnom Penh perceived higher science and mathematics performance than students from Kampong Cham, and students' performance from schools in Kampong Cham was higher than that of schools in Battambang. This was consistent with a report by MoEYS (2018g), which indicated that students in urban schools achieved better scores than those in rural schools by 51 score points in mathematics. However, in the second observation, schools in Kampong Cham had the highest perceived science and mathematics performance. Similar trends occurred for science and mathematics self-efficacy. Students from upper secondary schools in Kampong Cham seemed to have the highest science and mathematics self-efficacy versus students in Phnom Penh and Battambang. This finding is interesting, since school in Phnom Penh (the urban area) were hypothesized to have higher science and mathematics academic achievement and self-efficacy than those in the provinces (the non-urban area). However, this hypothesis was not accepted, especially for the second observation. According to MoEYS (2018g), as seen in Figure 6.3, in Cambodia, 8% of the 15-year-old students achieve a minimum proficiency level (level 2) or higher in reading, 10% in mathematics, and 5% in science.

Figure 6.3: Percentage of students aged 15 who reach the minimum proficiency level



Source: MoEYS (2018g)

With low science and mathematics performance, together with the diverse characteristics of upper secondary schools in the urban and rural areas regarding the quality of teachers (MoEYS, 2018h), the availability of teaching resources and school culture might also contribute to the diverse science and mathematics performance and self-efficacy levels relative to different locations (Woolnough, 1994b). Bandura (1986) indicated that there are four primary sources of science and mathematics self-efficacy, one of which is the academic achievement. Hence, as the students' performance in science and mathematics increased in upper secondary school in Kampong Cham, their science and mathematics self-efficacy might also increase. There might be one yet interesting fact to explain this phenomenon. According to the results of the national baccalaureate examination in 2019, among the three sampled provinces, Kampong Cham got the highest percentage of the student passing rate on the national examination. As evidence, 66.72% of the grade 12th students passed the examination while there were 57.88% and 64.63% of the students passed the national examination in Phnom Penh and Battambang, respectively (MoEYS, 2019d).

Third, there has been an interesting discourse among researchers on the different patterns of students' attitudes towards science relative to geographic region. Unlike what has been debated, this current study found that students from non-urban areas had higher positive attitudes towards science constructs than students from urban areas (Anwer, et al., 2012; George, 2000; Serin & Mohammadzadeh, 2008). Rather, the current study confirmed some other studies (see, for example, Hammrich, 1998; Zacharia & Barton, 2004), that due to environmental advantages, students from urban zones usually have higher attitudes towards science than students from non-urban areas. These results reflect the contextual reality that since students from the urban areas are presumed to be at an advantages in accessing more science interest-driven activities and facilities, students from these places are more likely to express higher attitudes towards science in the long run. The quality of mathematics and science instruction is impacted not only by the teacher quality, but also by access to quality materials and the curriculum (Eng & Szmodis, 2015). Thus, students with more access to quality science and mathematics lessons might be more likely to have higher attitudes towards science than those who do not. Schools in Phnom Penh and Kampong Cham performed better than schools in Battambang, especially regarding science as a practical subject and extracurricular activities in science.

Contextually, there are a few, yet interesting facts to explain this phenomenon. First, there are NGS in these two provinces. As stated in the NGS policy (MoEYS 2016c), one of the main goals of NGS is to introduce STEM and inquiry-based or project-based teaching. Therefore, interactive science and mathematics lessons and practical work in science, characteristics that are embedded in inquiry-based teaching, are much more common in NGS than in traditional schools. Second, the school facilities of NGS—from lab experiments and teaching and learning facilities to other extracurricular facilities—are essential to their characteristics (MoEYS 2018e). Therefore, these aspects might become advantages for NGS students in these two provinces, leading them to have higher scores on the constructs than students from traditional upper secondary schools in Battambang Province.

Fourth, it is indispensable to highlight the effect of school location on students' future plan in science. Overall, in both observations, students from upper secondary schools in non-urban areas had higher future plan in science than those from the urban area. Although in the first observation, schools in Phnom Penh seemed to perform better than schools in Battambang, the effect decreased such that their students were among the lowest groups willing to pursue science in the future. The effect size increased to .03 in the second observation. In a broader sense, this result was consistent with the review of the students' attitudes, for which future plan in science was included as a construct, with reference to the nationality perspective, whereby developing countries exhibited higher attitudes towards science than developed nations (Ye, et al., 1998). Further, students from non-urban areas have higher attitudes towards science than students from urban areas (Anwer et al., 2012; George, 2000; Serin & Mohammadzadeh, 2008, Kao, 2019a). These results come as a surprise, since the latter are presumed to be at an advantage in accessing more science interest-driven activities and facilities. However, in the Cambodian context, there might be a few interesting anecdotes to explain this phenomenon. First, it is generally believed that science subjects are more oriented to becoming science teachers at upper secondary school. Also, because students need to adjust to the norms of their parents (especially from those non-urban areas), who believed that becoming a teacher is one of the most secure and permanent jobs (i.e., civil servants), they are more likely to exhibit higher future plan in science in the long run.

Another possible explanation is that non-urban students consider science subjects to be ideal for a better future and to have a higher socio-economic status (Anwer et al., 2012; OECD, 2016). Therefore, non-urban students showed significantly higher future plan in science than urban students. On top of this, one of the striking differences between urban and non-urban students was self-interest in science and science activities, with (*M* = 3.36, *SE* = .04) among the former and (*M* = 3.44, *SE* = .04) among the later. This might be due to the fact that non-urban students are exposed more to a natural environment in which they can discover more to enhance their attitudes towards science in general, and their future plan in science in particular, compared to their urban counterparts.

Last but not least, interactive science and mathematics lessons were perceived differently relative to school location. Simply said, students from schools in the non-urban areas (Kampong Cham and Battambang) perceived that their science and mathematics lessons were more interactive than students from schools in the urban area (Phnom Penh). These differences occurred for both the first and second observations; from observations 1 to 2, the effect size changed from .04 to .09.

The finding is surprising, since the students from schools in the urban area has more advantages in accessing more qualified teachers and more interactive teaching facilities. This unexpected result can be explained by a few anecdotes. First, the selected upper secondary schools in Kampong Cham were the so-called NGS and the Resource Upper Secondary Schools. Empirically, the STEM-focused upper secondary schools student attendance enhanced interactive science and mathematics lessons compared to their counterpart schools. Teachers in STEM-focused schools were encouraged to implement interactive teaching and learning methods in the classrooms, including project-based learning, inquiry-based learning engaging STEM teaching, and real-world STEM experiences (Bicer et al., 2015; Mean et al., 2016). Seemingly, inquiry and thinking were highly valued and discussed within schools, but inquiry-based learning as pedagogy varied greatly in implementation across schools and disciplines. Teachers and students developed strong social interactions through group work, small school relationships, and peer teaching and learning, leading to higher learning outcomes in STEM-focused schools (Morrison et al., 2015). Second, one selected school in Battambang was a resource school. Secondary resource schools also have advantages in accessing teaching and learning facilities which could enhance science and mathematics teaching instruction. This school was reformed to have students streamed into the classes of mathematics, physics, and Khmer literature. After this reform, in academic year 2018–2019, students gained an increased number of learning hours in science and mathematics to double the normal school's learning hours.

6.5.4 Study track matters, yet it has a small effect

The bifurcation of science and the social science and the NGS exerted significant effects on all time-varying covariates in both the first and second observations. It is interesting to note that although NGS was hypothesized to have a larger effect than the science track of traditional upper secondary school, there was no significant difference between these two tracks for the constructs of science and mathematics self-efficacy, science and mathematics outcome expectations, science and mathematics self-concepts, interest in science at school, science activities outside school, future plan in science, and science and mathematics teachers' support. However, based on the strength of the effects, there are some interesting findings to be highlighted.

First, it is undeniable to highlight the effect of attending in different tracks on students' performance in science and mathematics as well as on science and mathematics self-efficacy. First, from the academic achievement perspective, it was found that students in NGS and in the science track at traditional upper secondary schools perceived higher performance and self-efficacy than students in the social science. This finding was in line with a broader perspective whereby students at STEM-focused upper secondary schools outperform their counterparts in traditional schools on mathematics and reading tests (Becker & Park, 2011; Bicer et al., 2015; Bicer et al., 2018; Han et al., 2016; Judson, 2014; Mean et al. 2016; Morrison et al., 2015; Scott 2012). STEM-focused schools can strengthen students' science and mathematics self-efficacy (Baran & Maskan, 2010), but their impact gradually declines (Zeng, Yao, Gu, & Przybylki, 2018). From a narrower perspective, the current study confirmed what other studies have found: Since students in the science track are more exposed to more science and mathematics courses at upper secondary school, they are more likely to have better achievement and higher self-efficacy in science and mathematics. This finding is not surprising and reflects the contextual reality of Cambodia. Students in NGS and the science track are exposed to more science and mathematics subjects than student in the social science track.

While the focus of the science track is on mathematics and science subjects (physics, chemistry, biology, and earth-environmental science) the social science track centres on Khmer literature, history, geography, and moral civics (MoEYS, 2010; MoEYS, 2018c). In NGS, the number of teaching hours for mathematics and other science subjects (physics, chemistry, biology, and computer science) was increased to six and four hours weekly, respectively. The total number of instructional hours is 34 hours a week for primary schools, and 40 hours a week for secondary schools. This required increase in instructional time is meant to provide students access to special subject themes that focus on STEM subjects, foreign languages, or other areas of interest to the local community. Also, students in NGS are streamed into mathematic, physics, chemistry, or biology classes (specialised class), since the higher number of instructional hours is ultimately meant to encourage more students to enrol in STEM-related fields in higher education. The increases teaching hours (which increased the students' exposure to science and mathematics subjects) and the focus on each science and mathematics class in NGS might lead higher students' performance and self-efficacy in science and mathematics subjects among those in the science track and NGS (versus students in the social science track).

Second, the tracking system at upper secondary school exhibited a significant impact on attitudes towards science constructs, including science as a practical subject, science and mathematics self-concepts, and interest in science at school. Students in the science track indicated significantly higher positive attitudes towards science than students in the social science track. However, it is surprising to note that there was no significant difference between students in NGS and student in the science track in traditional schools for the constructs of science and mathematics self-concepts, the importance of science in society, and interest in science activities at school. This finding corroborated with other research (George, 2006; Myeong, et al., 1991; OECD, 2016; Simpson & Oliver, 1990) that revealed that the number of science and mathematics classes taken at school is positively linked to one's attitudes towards science.

Contextually, according to announcement #23 of MoEYS, students in the science track need to take five hours/sessions of mathematics per week, while students in the social science only need to take two hours/sessions per week. Thus, greater exposure to science and mathematics, especially on the practical work of science, had a greater influence on students' positive attitudes towards science. Second, NGS employ more interactive teaching methods, such as inquiry-based or project-based learning (Bicer et al., 2015; Mean et al., 2016). These approaches not only foster active interest and interactions among teachers and students, but also involve more practical work in science (experiments) and engage students in their classroom activities (Keselman, 2003; National Research Council, 2000). Notably, the current study also confirmed recent studies that students' involvement in STEM extracurricular and out-of-school activities are common in STEM-focused upper secondary schools versus their traditional counterparts (Mean et al., 2016; Sahin, 2013).

Third, it is indispensable to highlight the effect of tracking on students' future plan in science. Students from the science track have stronger future plan in science than their peers in the social science track. However, students from NGS had lower future plan in science than students in the science track. This finding confirms that future participation in science is higher in STEM-focused schools (Kao & Shimizu, 2019; Shim & Park, 2013; Tofel-Grehl & Callahan 2014; Wang & Lee, 2019). Some researchers (George, 2006; Myeong, et al., 1991; OECD, 2016; Simpson & Oliver, 1990) have asserted that the number of science and mathematics classes taken in different tracks at school is positively linked to the level of attitudes towards science in general, and future participation in science in particular. While students in NGS are exposed to more science and mathematics classes, their participation in science after finishing upper secondary education is lower than students in the science track in traditional schools. There might be a few anecdotes to explain this phenomenon. First, some students might not attend NGS to build their future plan in science, but rather to build their capacity in general. One student from NGS said, "I have never thought about science or social science; I just want to study". Second, students from NGS might not have a clear plan for their future majors.

6.5.5 The effects of tracking across the two observations

The results across the two observations revealed that performance in science and mathematics, science and mathematics self-efficacy, science and mathematics self-concepts, the importance of science in society, interest in science at school, science activities outside school, extracurricular activities in science, and family encouragement and support increased from observations 1 to 2. However, there were decreasing trends for future plan in science and science and mathematics teachers' support in science. Based on the value of *Cohen's d* effect size, although there was a statistically significant difference across the two observations, only a few of the constructs had a *small effect* (extracurricular activities in science, performance in science and mathematics, family encouragement and support, science and mathematics self-concepts, and future plan in science) while the other had a *very small effect* in enhancing the constructs.

First, the increasing trend of *extracurricular activities in science*, a sub-construct of attitudes towards science, had one of the strongest effect sizes. The mean score increased from (M = 2.51) in the first observation to (M = 2.74) in the second observation. The effect size of d = .27 indicated a small effect. Also, *science and mathematics self-concepts*, another construct of attitudes towards science, exhibited a small effect (d = .17) of the increasing trend from observations 1 to 2. This finding showed a contrasting trend with the finding by George (2006), Hacieminoglu (2016), and Simpson and Oliver (1990), who discovered that students' attitudes towards science declined from the lower secondary school to the upper secondary school years. Since attitudes towards science are related to the science classes students take, this decline might be related to the type of science courses they take in each grade (Simpson & Oliver, 1990). In the Cambodian context, while students in grade 10th take the same number of science and mathematics lessons, students take a different number of science and mathematics lessons in grade 11th. Also, since students in grade 11th of NGS have a higher number of science and mathematics lessons, their attitudes towards science in general and attitudes towards extracurricular activities, as well as science and mathematics self-concepts, might also increase. Surprisingly, although there exhibited an increasing trend, the size of the effect was small. This might have little effect on enhancing students' aspirations of STEM majors in higher education.

Second, despite a small effect (with an effect size of d =.25), *performance in science and mathematics* increased from the first observation (M = 2.36) to the second observation (M = 2.50). Given this small increase, the finding was consistent with what the PISA-D assessment revealed: the students had a minimum proficiency level 2 (level 2 is the baseline competency level of the 6 levels of PISA-D or PISA), in line with the competency level that is the UN Sustainability Development Goad (SDG) #4 on Education (MoEYS, 2018g). Specifically, only 10% and 5% of students achieved the minimum proficiency level in mathematics and science, respectively.

Third, there is a statistically significant increase of perceived *family encouragement and support* in science from observations 1 to 2. The effect size was d =.18 which denoted a small effect. Family encouragement and support are crucial in students' lives including their educational choices (Simpkins et al., 2015). This might be unique in Asian culture, where family influence still weighs heavily in students' academic choice. Thus, the finding extends the understanding of culturally embedded phenomena in context, whereby students are prone to listening to parental advice, as parents are a primary source of academic and financial support (Bieri Buschor, Berweger, Keck Frei, & Kappler, 2014). As students moved up in grade level, their need for academic and financial supports also increased. Eng and Szmodis (2015) highlighted that with less than 2% of students enrolling in the sciences, it is reasonable to assume that many parents and students do not see the value of majoring in science when exploring profitable, prestigious career options. However, if parents and students are educated on the value of science as a discipline and lucrative future career choices, especially for females, there may be an increase in science as a major in higher education. The results of the qualitative interviews also triangulated the quantitative findings. In pursuing science, students need a lot of supports and encouragements from their parents because they need to spend both time and money on their studies. One respondent mentioned, *"When I am working on a project, I need to spend money on equipment, and I need time to do the project"*.

Future plan in science exhibited a worrisome declining trend from the end of grade 10th to the end of grade 11th, although the trend had a small effect size of d = .16. This finding is consistent with other studies (e.g., Chonkaew, Sukhummek, Faikhamta, 2016; George, 2006; OECD, 2016; Simpson & Oliver, 1990); that is, attitudes towards science generally declined throughout middle and high school. The most alarming trend is students' future participation in science. Empirically, students who were exposed to more science and mathematics classes were more likely to have higher participation in science or STEM in higher education. Nonetheless, this study seemed surprising as students who were exposed to more science and mathematics classes throughout the grade levels tended to decrease their level of future participation in science. The finding might be explained by a few interesting facts. First, the decline could be due to a lack of support from science and mathematics teachers. Teachers are encouraged to implement student-centered approaches (including inquiry or project-based learning) in which students are engaged in the learning process and motivated to be interested in science (Bicer et al., 2015). However, it was found that there was no significant change in interactive science and mathematics lessons across tracks throughout one academic year span. Empirically, it was also revealed that inquiry is not often used by primary (MoEYS, 2019b) and traditional upper secondary school science teachers, who are more teacher-centered (Sar, 2014) with little student interaction, teamwork, or problem-solving (World Bank, 2012). Thus, the variation in employing these approaches among Cambodian upper secondary school teachers might contribute to the phenomenon.

The investigation of the marginal means of the patterns of time-varying covariates, as a function of observation and study track, exhibited different trends of the constructs of the social science track, the science, and the NGS track across the two observations. There were both within and between group variations for the values of the constructs. Overall, students from NGS performed higher than students in the science track, and students in the science track performed better than students in the social science track. Based on the size of the effect, the notable effects were on future plan in science, performance in science and mathematics, extracurricular activities in science, family encouragement and support in science, science and mathematics self-concepts, science as a practical subject, and science and mathematics self-efficacy. Specifically, it is surprising to observe that future plan in science of the NGS and science track students decreased from observations 1 to 2, while the trend of student in the social science track slightly increased. This reflects a social problem; while most students chose the science track at upper secondary school, their participation in science or STEM majors in higher education decreased. This finding is in line with the long-term widespread decline in interest in science, which Dainton (1968) termed the phenomena as *"swing from science"*. This declining trend might also be explained by the shrinking support from science and mathematics teachers. As evidenced in the current study, support from science and mathematics in both the NGS and the science track decreased from observations 1 to 2. The trend was higher for students in the NGS than students in the science track of traditional schools.

Last, regarding performance in science and mathematics, NGS students outperformed students in the science track and social science track. However, there was a slight falling trend from observations 1 to 2, but the opposite trend for students in the science track and social science track. This trend might be contributed by the perceived declining trend of science as a practical subject. Moreover, NGS students employed more practical work in science subjects than students in the other two tracks. Third, there was between group and within group variation for extracurricular activities in science, with NGS students having the most advantages. Simply put, NGS students outscored students in the other two tracks (science and social science). The gap was even larger in the second observation. This finding is consistent with the unique characteristics of the so-called STEM focused schools. Students' involvement in STEM extracurricular and out-of-school activities, and interest in science careers and aspirations were significantly higher for student in STEM-focused schools than their non-STEM counterparts (Mean et al. 2016; Sahin 2013). More interestingly, similar trends occurred for the other two constructs of attitudes towards science: science and mathematics self-concepts and science as a practical subject. NGS students were exposed to more extracurricular activities in science including the STEM Bus, the STEM festival, and a robotic competition. This might have contributed to the higher score for extracurricular activities in the science participation of the students from NGS compared to their counterparts.

6.6 Concluding remarks

The students had a high level of science and mathematics outcome expectations, science as a practical subject, and the importance of science in society. However, science and mathematics self-efficacy, science and mathematics self-concepts, interest in science at school, science activities outside school, extracurricular activities in science, future plan in science, support from science and mathematics teachers, and interactive science and mathematics lessons were at a moderate level. Performance in science and mathematics was at a low level. More interesting, regarding patterns, there was no significant difference between males and females for most of the constructs. However, there was a significant difference between schools and study tracks. Simply said, schools in Kampong Cham tended to have a higher mean score on most of the constructs than schools in Phnom Penh and Battambang. Students from NGS tended to have a higher score than students in the other tracks (science and social science). Across one academic year span, students had uneven trends across the constructs. Some constructs exhibited increasing trends, while the other constructs showed a decreasing trend. This varied according to the covariates of gender, school location, and study track. This result could be concluded that, across one academic year span, although there was a significant influence of different tracks on the time-varying covariates, the tracks had small effects on improving the constructs, which influenced students' choice of the science track at upper secondary school and transition into STEM majors in higher education. The effect was in a negative trajectory for students' future plan in science. Surprisingly, there was no effect of different tracks on interactive science and mathematics lessons across the two observations. The trends and patterns of the constructs should also be considered from the angles of gender and school location.

CHAPTER SEVEN: ASPIRATIONS OF STEM MAJORS: FINDING III

Little is known about the actual effects of tracking system at the Cambodian upper secondary school level on students' aspirations of STEM majors in higher education. Thus, building upon the previous chapter on the effects of different tracks on trends of time-varying covariates and served as the main purpose of the current study, this chapter highlights the effects of tracking between the social science and science tracks at traditional upper secondary school, and the science track at new generation upper secondary schools and the other multi-dimensional variables (individual, family, and school) on students' aspirations of STEM majors in higher education. The chapter begins with the main question that guided the investigation in this chapter, followed by the method (samples and data analysis). Results, discussion, and a brief conclusion responding to *Research Question 3* come to serve as the closing section of this chapter.

In this chapter, the researcher addressed the following research question as follow.

RQ 3: What are the effects of the tracking system and other variables on Cambodian upper secondary school students' aspirations of STEM majors?

7.1 Method for RQ 3

7.1.1 Samples

The data for *Research Question 3* was the second wave data collected from 700 late grade 11th students (males = 310, females = 390) from nine upper secondary schools in Phnom Penh (N = 330) and two provinces (N = 370) (Kampong Cham and Battambang, located 124 and 291 kilometers from Phnom Penh, respectively). One significant justification for selecting this sample was that according to MoEYS (2010), by the end of 10th grade, students must choose to study in either the science track or social science track for their 11th and 12th grades. From this academic decision, the 11th grade students might have developed a clearer picture of what the science and social science tracks mean, and been able to sensitize the consequences of their track choice on higher education major. Furthermore, Simpkins et al. (2015) claimed that upper secondary school is the first time when students could drop out of science coursework, which could inadvertently close the doors to STEM opportunities. As such, any intervention should begin at this point.

Table 7.1 illustrates the details aspired majors of the interviewees (reported in the second wave) and the majors they ended up choosing (reported in the follow-up interviews). It is interesting to note that of the 25 interviewees from the science track at upper secondary school, 48% switched to non-STEM majors when they transitioned to higher education.

Table 7.1: Details on the interviewees' chosen majors

Transcript Number	Student Code	School Code	Gender	Major Aspiration (2^{nd} Observation)	Major Aspiration (Follow-up interview)
01	S655	09	Female	Accounting	Accounting
02	S679	09	Female	Tourism	Tourism
03	S043	01	Female	Doctor	Law
04	S336	05	Female	Tourism	Tourism
05	S319	04	Female	Economic	Business
06	S269	04	Male	Programming	Medicine
07	S538	07	Female	Accounting	Medicine
08	S267	04	Male	Law	Law
09	S284	04	Male	Science	Engineering
10	S302	04	Female	Medicine	Science
11	S671	09	Female	Food Chemistry	Food Chemistry
12	S298	04	Female	IR	Biotech
13	S668	09	Female	Doctor	Bio engineering
14	S643	08	Female	Physics	Physics
15	S677	09	Male	Computer science	Computer science
16	S669	09	Female	Doctor	Pharmacy
16	S670	09	Male	Doctor	Pharmacy
17	S639	08	Female	Tourism	Tourism
17	S641	08	Female	Law	Law
17	S647	08	Male	Marketing	Medicine
17	S614	08	Male	Marketing	Marketing
18	S428	06	Female	Tourism	Law
18	S452	06	Female	Accounting	Accounting
19	S674	09	Male	Computer science	Computer science
19	S675	09	Male	Computer science	Law

7.1.2 Data analysis method

To address *Research Question 3*, which aimed to investigate the effects of tracking and the other three-dimension variables on students' aspirations of STEM majors in higher education, *Hierarchical Linear Modeling 8* (HLM-8) was employed to analyze the data structure, where 700 students (Level-1) were nested within 21 classes (Level-2). Hierarchical Linear Modeling was employed instead of Binary Logistic Regression because the researcher aimed to investigate if there were any class differences when students were nested in different classes. In a sense, the practices in the science track and social science tracks might have had different levels of influence on students' aspirations of STEM majors in higher education. Put simply, of the specific interest were the relationships among Cambodian upper secondary school students' aspirations of STEM majors (the outcome variable in level-1) and individual students' ability and motivational beliefs, and family background and encouragement (level-1 predictor variables) and their track, experience, and support in science and mathematics classrooms (level-2 predictor variables). While logistic regression is also appropriate for analyzing student-level data, a single-level regression analysis is considered to have breached a number of assumptions when applied to multi-level/nested data. A single-level regression analysis, when used with data that are highly structured at different levels, likely produces a much-biased estimation of the resultant standard errors in the analysis (Type I error; Raudenbush et al., 2019; Woltman et al., 2012)

A multi-level model is highly suggestive because it accounts for the shared variance in hierarchically structured data. It accurately estimates the lower level slope and its estimation of higher-level outcome (Woltman et al., 2012). In addition, multi-level analysis was the most appropriate for this study since the data had nested and hierarchical structures. Each student was nested within each class. Therefore, predictor variables at level-1 were, in principle, nested within level-2. Prospective data consisted of independent variables or predictors variables which were organized in two hierarchical levels: individual (family background included) and upper secondary school.

To analyze the data, model testing proceeded in four phases (Raudenbush et al., 2019; Woltman et al., 2012): (1) unconditional (null) model (only the outcome variable was included in the model); (2) the random intercepts model (only level-1 variables); (3) the means-as-outcomes model (only level-2 variables); and (4) the random intercepts and slopes model (the final model of level-1 and level-2 variables). Because the outcome variable was dichotomously coded (STEM versus non-STEM majors), *Bernoulli Method with Restricted Maximum Likelihood Method* (RMLM) of estimation was employed to analyze the nested data structure. This main research question aimed to determine the effects of tracking and individual, family, and upper secondary school-related factors on Cambodian upper secondary school students' aspirations of STEM majors in higher education. This question involved a hierarchy with two levels. Classroom-level related variables were at the highest level (level-2) which included predictor variables such as the tracking system, science and mathematics teachers' support, and interactive science and mathematics lessons. Level-1 variables consisted of measurements on gender, hours spent self-studying science, academic achievement, performance in science and mathematics, science and mathematics outcome expectations, science and mathematics self-efficacy, future plan in science, constructs of attitudes towards science (science as a practical subject, science and mathematics self-concepts, the importance of science in society, science activities outside school, and extracurricular activities in science). This level also included predictor variables related to individual students' family characteristics such as father's education, mother's education, relative's majors, family income, and family encouragement and support). Level-1 variables at the lowest level of the hierarchy were nested with level-2 groups and shared the influence of level-2 variables. The outcome variable, aspirations of STEM majors, was also measured at level-1. In principal, the outcome variable should always be located at the lowest level of the hierarchy in the HLM model (Raudenbush et al., 2019).

As briefly stated, the two-level HLM analysis started with a null model to examine the amount of variability in the Cambodian upper secondary school students' aspirations of STEM majors that was attributable to students and classroom levels (Raudenbush et al., 2019; Woltman et al., 2012). The null model estimated the variances of the "intercepts" at all the two levels and contained no predictor variable from any level. The intercept represented the mean scores of students' aspirations of STEM majors for each class. According to Raudenbush et al. (2019) and Woltman et al. (2012), the first step of HLM is to evaluate the level-2 variance components in order to determine if there is statistical justification for running HLM analyses. The null model produced the *chi-square* tests of the between-class variance components, which evaluated whether there were statistically significant differences in the students' aspirations of STEM majors in higher education across level-2, that was between the classes the students were in (Woltman et al., 2012).

The examination of the variance components in the null model provided the estimates for the proportions of the between students and between classes related factors. This variance component was fundamental, since it served as the baseline against which the variability in the students' aspirations of STEM majors in the random intercept model, as well as the subsequent models was explained.

As the name implies, this two-level model consisted of two sub-models at level-1 and level-2. Level-1 represents the relationships among the individual student-level variables, while the level-2 model captures the influence of classroom-level factors. Specifically, there were $i = 1, \ldots, n_j$ level-1 units (individual students) nested within $j = 1, \ldots, J$ level-2 units (classrooms). The level-1 and level-2 models are as presented below:

Level-1 Model

$$\text{Prob}(STEM\ MAJOR_{ij}=1|\beta_j) = \phi_{ij}$$
$$\log[\phi_{ij}/(1 - \phi_{ij})] = \eta_{ij}$$
$$\eta_{ij} = \beta_{0j}+\beta_{1j}X_{1ij}+\beta_{2j}X_{2ij}+\ldots\ldots+\beta_{Qj}X_{Qij}+r_{ij}$$

where β_{0j} is the level-1 intercept for students in a given class j, X_{Qij} is the level-1 predictor q for case i in the unit j, and r_{ij} is the level-1 residual/student i's deviation from β_{0j}.

Level-2 Model

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where γ_{00} is the average intercept across classrooms, and u_{0j} is classroom j's deviation from γ_{00} (Raudenbush et al., 2019).

The models employed in the current study were developed based on the general principles for the level-1 and level-2 models noted above. Below is a summary of the current study's level-1 and level-2 models estimation. The model captured all predictors that were included in the two-level HLM analysis.

Level-1 Model

In level-1, the probability of students choosing STEM as their major is a function of classroom mean and the slopes.

Prob($STEMMAJOR_{ij}$=1|β_j) = ϕ_{ij}

log[ϕ_{ij}/(1 - ϕ_{ij})] = η_{ij}

$\eta_{ij} = \beta_{0j} + \beta_{1j}*(GENDER_{ij}) + \beta_{2j}*(PERSOCSU_{ij}) + \beta_{3j}*(PERSCISU_{ij}) + \beta_{4j}*(SCIPRASU_{ij})$

$+ \beta_{5j}*(SCISELCO_{ij}) + \beta_{6j}*(IMPSCI_{ij}) + \beta_{7j}*(SCIACTOU_{ij}) + \beta_{8j}*(EXTACURS_{ij})$

$+ \beta_{9j}*(FUTPLANS_{ij}) + \beta_{10j}*(SCIMATHE_{ij}) + \beta_{11j}*(SCIMATHO_{ij}) + \beta_{12j}*(ACADACHI_{ij})$

$+ \beta_{13j}*(LEARNHOU_{ij}) + \beta_{14j}*(FATHERED_{ij}) + \beta_{15j}*(MOTHERED_{ij}) + \beta_{16j}*(RELATIVE_{ij})$

$+ \beta_{17j}*(FAMINCOM_{ij}) + \beta_{18j}*(FAMILYST_{ij}) + \beta_{19j}*(FAMENCOU_{ij})$

Note: GENDER = Gender, PERSOCSU = Performance social subjects, PERSCISU = Performance science subjects, SCIPRASU = Science as a practical subject, SCISELCO = Science self-concept, IMPSCI = Importance of science, SCIACTOU = Science outside school, EXTACURS = Extracurricular activities in science, FUTPLANS = Future plan in science, SCIMATHE = Science and mathematics self-efficacy, SCIMATHO = Science and mathematics outcome expectation, ACADACHI = Academic achievement, LEARNHOU = Hours spent self-studying at home, FATHERED = Father's education, MOTHERED = Mother's education, RELATIVE = Relative's major, FAMINCOM = Family income, FAMILYST = Family status, FAMENCOU = Family encouragement and support.

Level-2 Model

Each level-1 variable became a level-2 outcome variable.

$\beta_{0j} = \gamma_{00} + \gamma_{01}*(TRACKING_j) + \gamma_{02}*(INTERACTIVE_j) + \gamma_{03}*(SCIMATHS_j) + u_{0j}$

$\beta_{1j} = \gamma_{10}$

$\beta_{2j} = \gamma_{20}$

$\beta_{3j} = \gamma_{30}$

$\beta_{4j} = \gamma_{40}$

$\beta_{5j} = \gamma_{50}$

$\beta_{6j} = \gamma_{60}$

$\beta_{7j} = \gamma_{70}$

$\beta_{8j} = \gamma_{80}$

$\beta_{9j} = \gamma_{90}$

$\beta_{10j} = \gamma_{100}$

$\beta_{11j} = \gamma_{110}$

$\beta_{12j} = \gamma_{120}$

$\beta_{13j} = \gamma_{130}$

$\beta_{14j} = \gamma_{140}$

$\beta_{15j} = \gamma_{150}$

$\beta_{16j} = \gamma_{160}$

$\beta_{17j} = \gamma_{170}$

$\beta_{18j} = \gamma_{180}$

$\beta_{19j} = \gamma_{190}$

Note: TRACKING = Tracking system*,* INTERACTIVE = Interactive science and mathematics lessons, SCIMATHS = Science and mathematics teachers' support

7.2 The effects of tracking and other variables on students' aspirations of STEM majors

7.2.1 Descriptive results

Based on the conceptual framework discussed in the previous chapter, current study classified the variables into two levels, with three dimensions of multiple variables. While level-1 variables cover the individual and family dimension variables, level-2 consists of the variables at classroom dimension. Table 7.2 illustrates the descriptive statistics (mean, standard deviation, and minimum and maximum) of these three-dimension variables included in the *Hierarchical Linear Model* (HLM) analysis. To reiterate, since the dependent variable was coded dichotomously (aspirations of STEM versus non-STEM related majors), *Bernoulli Method with Restricted Maximum Likelihood Method* (RMLM) distribution was selected as the main analytical method responding to research question 3. The results from the analysis were interpreted in terms of *log odds*: the change of the outcome variable resulting from a unit of change in the predictor variables. Table 7.2 depicts the details descriptive statistics of the variables included in the two-level HLM analysis.

Table 7.2: Descriptive statistics of the variables included in the HLM analysis

Level-1 Descriptive Statistics					
Variable name	***N***	**Mean**	**SD**	**Minimum**	**Maximum**
Individual Level Predictors					
Gender (female)	700	-	-	0	1
Hours spent self-studying science	700	3.05	2.34	00	16.50
Academic achievement	700	469.42	98.27	00	654
Performance in science and math	700	2.50	0.77	1	4.60
Science and math outcome expectations	700	3.88	0.58	1.71	5
Science and math self-efficacy	700	3.07	0.64	1	5
Future plan in science	700	3.46	0.83	1	5
Science as a practical subject	700	3.61	0.69	1	5
Science and math self-concept	700	2.88	0.66	1	5
Importance of science in society	700	3.90	0.57	1.80	5
Science activities outside school	700	3.54	0.68	1	5
Extracurricular activities in science	700	2.74	0.78	1	5
Choice of Major (STEM) ***(Outcome)***	700	-	-	0	1
Family Level Predictors					
Father's education	700	2.18	1.48	1	6
Mother's education	700	1.85	1.26	1	6
Relatives' major (STEM)	700	-	-	0	1
Family income	700	2.34	1.09	1	4
Family encouragement and support	700	3.48	0.60	1	5

Level-2 Descriptive Statistics					
Variable name	***J***	**Mean**	**SD**	**Minimum**	**Maximum**
Classroom Level Predictors					
Tracking (science)	21	-	-	0	1
Science and math teachers' support	21	4.13	0.71	3	5.44
Interactive science and math lessons	21	2.81	0.48	1.71	3.71

Note: J = Number of class

The descriptive statistics showed some basic findings related to individual students and the characteristics of the other dimension variables. First, since gender was measured as a categorical measurement, mean score calculation was not applicable. However, based on the descriptive statistics, 55.7% of the sample was female, while 44.3% was male. Next, hours spent self-studying science subjects comprised the average number of hours students spent learning or doing science and mathematics subjects at home per week. On average, students spent about 3 hours (*M*=3.05, *SD*=2.34) on their outside classwork self-studying. With regard to academic achievement, with a total score of 825 (based on MoEYS' guidelines), most students only scored above average (*M*=469.42, *SD*=98.27). Likewise, on a five-point-Likert scale (ranging from average to excellent), students' performance in science and mathematics subjects was just above average (*M*=2.50, *SD*=0.77). With this just above average performance, although the samples had higher level of science and mathematics outcome expectations (*M*=3.88, *SD*=0.58), they had a moderate level of science and mathematics self-efficacy (*M*=3.07, *SD*=0.64). Moreover, they had higher future plan in science (*M*=3.46, *SD*=0.83). Most of note, for the attitudes towards science sub-constructs, the students had a higher view of the practicality of science subjects (*M*=3.61, *SD*=0.69), lower science and mathematics self-concepts (*M*=2.88, *SD*=0.66), higher attitudes towards the importance of science in society (*M*=3.90, *SD*=0.57), higher attitudes towards science activities outside school (*M*=3.54, *SD*=0.68), and just a moderate level of attitudes towards extracurricular activities in science (*M*=2.74, *SD*=0.78).

On the other continuum, for the family-level predictors, which were also included as level-1 predictors in the HLM analysis, most of the students' fathers had finished upper secondary school (*M*=2.18, *SD*=1.48); their mothers had even a lower level of education (*M*=1.85, *SD*=1.26). Another characteristic of family-level predictors, family monthly income, seemed to fall between 200 USD to 400 USD (*M*=2.34, *SD*=1.09). Lastly, reflective of Cambodia's supportive culture, the students tended to receive a higher level of encouragement and support from their families (*M*=3.48, *SD*=0.60).

There were three main variables of level-2 (the classroom level) predictors included in the HLM analysis. First, since the tracking system was measured on nominal measurements, mean score was not computed. However, based on descriptive analysis, 36.7% of the samples were in the social science track, and 63.3% were in the science track. There seemed to be an imbalance between students in the two tracks since only science classes were offered at the two selected NGS in Phnom Penh and Kampong Cham Province. Second, the students seemed to have received moderate support from their science and mathematics teachers for their aspirations of STEM majors (*M*=4.13, *SD*=0.71). However, the teaching of science and mathematics lessons was not very interactive (*M*=2.81, *SD*=0.48).

7.2.2 Unconditional (null) model: Only the outcome variable

As a result, from the Hierarchical Linear Modeling (HLM) analysis, Table 7.3 illustrates the factors associated with grade 11th students' aspired higher education majors. As in the first step, an unconditional model was performed to confirm that the variability in the outcome variable (STEM major), by level-2 variables, was significantly different from zero. In this model, there was no other predictor variable. Rather, there was only the outcome variable, which should be in level-1. This tested whether there were any differences at the group level for the outcome variable, and confirmed whether HLM was necessary. The analysis supported this hypothesis. Put simply, the intercept only model (the unconditional model) estimated a χ^2 (20) = 117.44, $p < 0.001$. The data showed a significant variance in upper secondary school students' aspirations of STEM majors in higher education.

Table 7.3: Final estimation of the variance components (intercept, u_0)

Random Effect	Standard Deviation	Variance Component	d.f.	χ^2	*p*-value
INTRCP1, u_0	0.84862	0.72016	20	117.43565	<0.001

The null model also showed the *Intraclass Correlation Coefficient* (ICC), which was calculated to assess the amount of between class variations. Therefore, the proportion of the variance component (the ICC) is calculated by the following equation:

$$\textbf{ICC} = \frac{\tau_{00}}{\tau_{00}+\sigma^2} = \frac{Level-2\ variance\ of\ the\ intercept}{Total\ variance\ components}$$

where τ_{00} is the estimated variance component of the intercept (u_0), and the variance σ^2 of the level-1 residual term in the model (Woltman et al., 2012; Wu et al., 2012).

However, this standard ICC formulation is not appropriately valid in the case of binomial hierarchical models since the distribution of the response is not continuous (McMahon et al., 2005; Raudenbush & Bryk, 2002; Raykov & Marcoulides, 2015; Wu et al., 2012); and that logistic regression analysis was the approach that can be used to fit the two-level model with a discrete outcome. Also, it is well-known that the standard logistic distribution of relevance has a variance of $\pi^2/3$. Therefor, the formula for calculating the ICC of the binary outcome model is:

$$\textbf{ICC} = \frac{\tau_{00}}{\tau_{00}+\pi^2/3}$$

Based on this formula, the ICC was **18**% (ICC = 0.18):

$$\textbf{ICC} = \frac{\tau_{00}}{\tau_{00}+\sigma^2/3} = \frac{0.72}{0.72+3.29} = \frac{0.72}{4.01} = \textbf{0.18}$$

According Raudenbush et al. (2019) and Woltman et al. (2012), this value represents the fact that 18% of the variance in Cambodian students' aspirations of STEM majors was between class, and 82% of the variance in their choice was between students within a given class. In this token, Hierarchical Linear Model (HLM) fits well with this data structure, whereby individual students (*N* = 700) were nested in classes (*J* = 21). By the same token, it was necessary to conduct the analysis using the HLM model. Furthermore, because variance existed at both levels of the data structure, predictor variables were individually added by each level into the analytical model.

7.2.3 Random intercepts model: Level-1 predictors (individual and family)

The random intercepts model was tested using individual factors (ability and motivational beliefs), and family background and encouragement and support as the only predictor variables. First, as illustrated in Table 7.4, of the variables included, the HLM results revealed the negative significant influence of *gender* (b = -0.67, p < 0.001) on Cambodian upper secondary school students' aspirations of STEM majors. Simply explain, unlike the choice of the science track at upper secondary school, female students were less likely to choose STEM majors in higher education than their male counterparts.

Within the category of gender, the students (25%) commented on their perceptions of gender in relation to their perceived characteristics of a STEM career. One girl commented, “My aunt urged me to choose law and said this major is good for women”. Another girl highlighted, “I chose accounting because of the working environment; I can work in an airconditioned room”. The third female students remarked, “I feel that my parents will not advise their children, females like me, to major in STEM-related, as they believe I will be lonely because these majors are male-dominated”. In short, the qualitative findings revealed that female students were less likely to choose STEM majors not because of their academic achievement, but due to the influence of their family members and their perceived characteristics of STEM majors, as well as of STEM careers.

Second, the model also pointed out to the influence of *academic achievement* (b = 0.36, p < 0.05) on Cambodian upper secondary school students’ aspirations of STEM majors in higher education. Students who had higher academic achievement were more likely to choose to a STEM major in higher education. Statistically, the odds of students’ aspirations of STEM majors increase by 1.44 times if academic achievement increases in one unit. The predictability was significant ($p<0.05$).

In the category of academic preparedness, the students (84%) mentioned that they aspired to major in a STEM-related field because they had a strong academic background. Students in the science track who aspired to major in STEM highlighted the influence of academic achievement. Stronger academic achievement influenced them to take STEM because such majors required students to be competent in science and/or mathematics subjects. For example, one student mentioned, “For higher education, I will choose biological engineering because my achievement is good, especially in mathematics, biology, and chemistry”. Another girl who chose physics said, “I have been good at physics since I was in grade 7^{th}”.

From attitudes towards science perspective, *future plan in science* was also one of the most significant predictors of students’ aspirations of STEM majors in higher education (b = 1.17, p < 0.001). Students who have a clearer future plan in science are more likely to choose STEM related majors when they are transitioning from upper secondary school to higher education by a factor of 3.32 times higher than their lower counterparts. Thus, having higher future plan in science leads students to have strong aspirations of STEM related majors in higher education.

Within this category, the interviews indicated that students who aspired to major in STEM fields tended to have a clearer future plan in science than those who did not, or those who switched to non-STEM majors. For example, one student explained, “I do not choose other major than physics to pursue in higher education because it is my long-term plan”. Students switched to non-STEM fields because they did not have a clear plan of what they would major in higher education. Students commented, “I choose science simply because I can pursue a doctor or engineering, or I can change to a non-STEM related majors in higher education”.

Table 7.4: Estimation of the random intercept model: Level-1 predictors

	Random Intercept Model		
	β	*SE*	*Odd Ratio*
Final effects intercepts	-0.25	0.21	0.78***
Level-1			
Individual Level Predictors			
Gender (Female)	-0.67	0.15	0.51***
Hours spent self-studying science	0.01	0.05	1.01
Academic achievement	0.36	0.15	1.44*
Performance in science and math	0.27	0.16	1.32
Science and math outcome expectations	0.18	0.18	1.19
Science and math self-efficacy	-0.19	0.19	0.82
Future plan in science	1.17	0.22	3.32***
Science as a practical subject	-0.12	0.16	0.88
Science and math self-concept	0.03	0.18	1.03
Importance of science in society	-0.34	0.26	0.71
Science activities outside school	-0.05	0.12	0.95
Extracurricular activities in science	-0.13	0.12	0.88
Family Level Predictors			
Father education	0.02	0.08	1.02
Mother education	-0.01	0.07	0.98
Relatives’ major (STEM)	-0.08	0.19	0.92
Family income	-0.07	0.09	0.93
Family encouragement and support	0.38	0.18	1.47*
Log-Likelihood	-9.38		
Chi-square statistics	141.38		
P-value	<0.001		

Note: * when p < .05; *** when p < .001

Last, from the family dimension predictors, of the variables included in the analysis, only *family encouragement and support* exhibited a significant effect ($b = 0.38$, $p < 0.05$). Students who have received more encouragement and support from their families to pursue science are more likely to choose STEM majors by a factor of 1.47 times higher when transitioning from upper secondary school to higher education. Therefore, the random intercepts model revealed that individual ability and motivational belief (including gender, academic achievement, and future plan in science) and family/social encouragement had significant, predictive roles in aspirations of STEM majors among Cambodian upper secondary school students.

Within this category, the qualitative data signalled that the students (64%) would be more likely to choose STEM majors if they had greater family encouragement and support in science. The respondents referred to their parents playing a role in their STEM-oriented goals. They explained that STEM majors tended to require more time and money. Therefore, stronger support from one's family enables students to choose a STEM majors. One representative student who switched from non-STEM to STEM expressed the following:

> I changed because of family encouragement and support. At first, I thought that my family could not support me, and I did not know if my parents would allow me to pursue science or not. One day they asked me what I wanted to study at university; I told them that I wanted to study marketing. Then they said "No, if you want to go to university, please go into the health sciences and we will support you". Then I followed their advice.

7.2.4 The means-as-outcomes model: Level-2 predictors

Next, the means-as-outcomes model added tracking and classroom experience and support as level-2 predictor variables, while holding the individual ability and motivational beliefs and family background and encouragement variables constant. Surprisingly, *tracking system* (science versus social science)—which was hypothesized to have significant predictability in one's choice of STEM majors—did not have any significant influence on Cambodian upper secondary school students' aspirations of STEM major in higher education ($b = 0.74$, $p > 0.05$). To reiterate, the students' choice of STEM major was not associated with their science track placement at the upper secondary school level.

Follow-up interviews further discovered that, within the final theme, the tracking system of the science track in traditional schools and NGS and the social science track, did not play much of a role in the students' aspirations of STEM majors. Most of the science track interviewees (48%) tended to switch to non-STEM majors at a considerable rate. Students

(32%) who changed from the science track to non-STEM majors recounted that their choice of the science track was an *"open choice"* in relation to higher education majors, and not specifically orientated toward STEM. The students explained that "Taking science has a lot of potential; you could pursue either a STEM or non-STEM field in higher education. However, if you took the social science, you would not have a strong background to change to STEM".

The regression coefficient relating to Cambodian grade 11th students' aspirations of STEM majors was significantly influenced by *interactive science and mathematics lessons* ($b = 1.28$, $p < 0.01$). This indicates the effects of how science and mathematics teachers convey messages to students in the classroom. For the measurement of the effect size, the explained variance in the aspirations of STEM majors by the level-2 predictor variables, was explained by **51**%:

$$\text{Variance explained} = \frac{Unconditional - Mean\ as\ outcome}{Unconditional}$$

$$\frac{0.72-0.35}{0.72} = 0.51 = 51\%$$

Thus, 51% of the between class measures variance of interactive science and mathematics lessons explained the variance in students' aspirations of STEM majors. This highlights the predictive magnitude of interactive science and mathematics lessons on students' choice of a STEM major. Table 7.5 illustrates the estimation of the means-as-outcome model; that is, the estimation of the effect of the level-2 predictor variables on Cambodian upper secondary school students' aspirations of STEM majors in higher education.

Table 7.5: Estimation of the means-as-outcomes model: Level-2 predictors

	Means-as-Outcomes Model		
	β	*SE*	*Odd Ratio*
Final effects intercepts	-0.26	0.16	0.77**
Level-2			
Classroom Level Predictors			
Tracking (Science)	0.74	0.44	2.10
Science and math teachers' support	-0.05	0.31	0.95
Interactive science and math lessons	1.28	0.27	3.58**
Log-Likelihood	-9.73		
Chi-square statistics	70.94		
P-value	<0.001		

Note: ** when p < .01

Within this last category, interactive science and mathematics lessons, the students (80%) in the interviews shared the same thought that beyond the effect of being in a different track, science and mathematics lessons influenced their interest in pursuing science. One girl who switched from a non-STEM to a STEM major in higher education explained the following:

> First, I was thinking of studying international relations, but when I experienced with a lot of interactions through experiments in science class, my thoughts changed a lot. I enjoy learning about science and feel that it is easy. Before I thought that it was difficult since it involves with complex formulas, but now I feel that it is much easier than the social science related fields. Then I changed to telecommunications.

Another student who switched from the science track at upper secondary school to a non-STEM major in higher education felt that the teaching practices of science and mathematics teachers were not, to some extent, interactive. She highlighted that:

> The teacher gave explanations and asked the students to do the exercises, but his explanations were sometimes one-way communication. He asked students to give answers, but it was not very active. And if we talked about group work or group discussion approaches employed in the classroom setting, it would be very seldom.

Therefore, interactive science and mathematics lessons (how science and mathematics teachers conducted their lessons) mattered for the students' interest in the science track at upper secondary school, and consequently influenced their aspirations of STEM majors in higher education.

Moreover, because the HLM analysis revealed that the part of upper secondary schools that influenced the students' aspirations of STEM majors in higher education was *interactive science and mathematics lessons*, the researcher further conducted logistic regression analysis to gain insight into this significant predictor. Using upper secondary school 9 as a baseline, logistic regression exhibited that being in upper secondary school 1 increased students' aspirations of STEM majors by more than two times (Exp(B) = 2.26; $p < .05$) higher. While being in upper secondary school 4 increased more aspirations of STEM majors by a factor of 3.36 times (Exp(B) = 3.36; $p < .001$), being in upper secondary school 5 increased students' aspirations by 7.03 times higher (Exp(B) = 7.03; $p < .001$). Lastly, being in upper secondary school 7, increased the odds of choosing a STEM major in higher education by a factor of 2.35 times higher than the baseline (Exp(B) = 2.35; $p < .05$; see Table 7.6 for details).

Table 7.6: The influence of upper secondary school on students' aspirations of STEM majors

School ID	B(SE)	95.0% C.I. for EXP(B)		
		Lower	Exp(B)	Upper
Constant	-.225(.076)***		.798	
Upper secondary school 1	.82(.34)*	1.17	2.26	4.36
Upper secondary school 2	.33(.37)	0.67	1.40	2.90
Upper secondary school 3	-.18(.38)	0.41	0.85	1.76
Upper secondary school 4	1.21(.33)***	1.74	3.36	6.48
Upper secondary school 5	1.95(.41)***	3.13	7.03	15.78
Upper secondary school 6	.27(.37)	0.63	1.30	2.69
Upper secondary school 7	.85(.35)*	1.18	2.35	4.65
Upper secondary school 8	.43(.33)	0.80	1.54	2.96
Cox & Snell R Square	.092			
Nagelkerke R Square	.123			

Note: * when p < .05; *** when p < .001

Descriptive statistics also revealed that upper secondary school 4, upper secondary school 5, and upper secondary school 7 had a higher mean score for interactive science and mathematics lessons (M = 2.98, SD = .52; M = 2.98, SD = .45; and M = 3.00, SD = .47), respectively than other schools. Therefore, it could be concluded the more interactive science and mathematics lessons are, the more likely the students are to choose a STEM major.

7.2.5 The random intercepts and slopes model: Mixed-level predictors

Finally, the study conducted the random intercepts and slopes (level-1 and level-2 variables) model, with all predictor variables included to examine if there was any interaction between predictor variables from the individual and family dimension (level-1) and the classroom dimension (level-2) on Cambodian upper secondary school students' aspirations of STEM majors in higher education.

As illustrated in Table 7.7, there was cross-level interaction between predictor variables at the individual and family and classroom levels. It was revealed that *gender* remained to be a negative significant predictor of students' aspirations of STEM majors in higher education, but the magnitude seemed lower (b = -0.75, p < 0.001). Statistically, the odds ratio decreased from 0.51 to 0.47. This means that by including the level-2 variables, female students tended to be less likely to choose STEM majors in higher education. Put simply, the inclusion of the classroom-level predictors, female students were less likely to be encouraged to pursue STEM majors in higher education at a higher rate than in the first model. While in the first model, female students were less likely to take STEM major by 49% compared to male students, in the second model, this figure increased to 53%.

Table 7.7: Estimation of the random intercepts and slopes model: Mixed-level predictors

	Random Intercepts and Slopes Model		
	β	*SE*	*Odd Ratio*
Final effects intercepts	-0.28	0.19	0.75***
Level-1			
Individual Level Predictors			
Gender (Female)	-0.75	0.20	0.47***
Hours spent self-studying science	0.07	0.04	1.00
Academic achievement	0.39	0.18	1.48*
Performance in science and math	0.32	0.21	1.37
Science and math outcome expectations	0.19	0.22	1.21
Science and math self-efficacy	-0.22	0.25	0.80
Future plan in science	1.30	0.17	3.68***
Science as a practical subject	-0.14	0.20	0.87
Science and math self-concept	0.02	0.22	1.03
Importance of science in society	-0.37	0.23	0.69
Science activities outside school	-0.04	0.18	0.96
Extracurricular activities in science	-0.15	0.15	0.86
Family Level Predictors			
Father education	0.02	0.09	1.02
Mother education	-0.09	0.10	0.99
Relatives' major (STEM)	-0.09	0.20	0.91
Family income	-0.09	0.10	0.91
Family encouragement and support	0.41	0.22	1.51*
Level-2			
Classroom Level Predictors			
Tracking (Science)	0.91	0.47	2.48
Science and math teachers' support	-0.08	0.37	0.93
Interactive science and math lessons	1.58	0.53	4.89**
Log-Likelihood	-9.55		
Chi-square statistics	85.41		
P-value	<0.001		

Note: * when p < .05; ** when p < .01; *** when p < .001

More interestingly, other level-1 predictors, including grade 11th academic achievement (b = 0.39, $p < 0.05$), future plan in science (b = 1.30, $p < 0.001$), family encouragement and support (b = 0.41, $p < 0.05$), and interactive science and mathematics lessons (b = 1.58, $p < 0.01$), remained to be the predictors accounting for the increasing odds of Cambodian upper secondary school students' aspirations of STEM majors in higher education. The odds of each variable also increased in the random intercepts and slopes model accordingly. The odds ratio for academic achievement increased from 1.44 to 1.48, future plan in science increased from 3.32 to 3.68, and family encouragement and support increased from 1.47 to 1.51, from the random intercepts (level-1) model to the random intercepts and slopes model (mixed-level), respectively.

Most notable is the effect of interactive science and mathematics lessons, for which the odds increased from 3.58 to 4.89, with $p < 0.01$, when level-1 and level-2 predictors were included. Therefore, considering the individual, family, and classroom-level variables, students take the interactive science and mathematics lessons they have experienced at upper secondary school into account when deciding on their aspirations of STEM majors in higher education. Table 7.8 presents a holistic view of the result of HLM analysis when all individual characteristics and family background (level-1) and classroom-level dimensions of upper secondary school supports (level-2) were included in the model.

Table 7.8: Hierarchical linear model of students' aspirations of STEM majors in higher education

	Unconditional Model			***Random Intercept Model***			***Means-as-Outcomes Model***			***Random Intercepts and Slopes Model***		
	β	SE	Odd Ratio	β	SE	Odd Ratio	β	SE	Odd Ratio	β	SE	Odd Ratio
Final effects intercepts	-2.25	0.20	0.78***	-0.25	0.21	0.78***	-0.26	0.16	0.77**	-0.28	0.19	0.75***
Level-1												
Individual Level Predictors												
Gender (Female)				-0.67	0.15	0.51***				-0.75	0.20	0.47***
Hours spent self-studying science				0.01	0.05	1.01				0.07	0.04	1.00
Academic achievement				0.36	0.15	1.44*				0.39	0.18	1.48*
Performance in science and math				0.27	0.16	1.32				0.32	0.21	1.37
Science and math outcome expectations				0.18	0.18	1.19				0.19	0.22	1.21
Science and math self-efficacy				-0.19	0.19	0.82				-0.22	0.25	0.80
Future plan in science				1.17	0.22	3.32***				1.30	0.17	3.68***
Science as a practical subject				-0.12	0.16	0.88				-0.14	0.20	0.87
Science and math self-concept				0.03	0.18	1.03				0.02	0.22	1.03
Importance of science in society				-0.34	0.26	0.71				-0.37	0.23	0.69
Science activities outside school				-0.05	0.12	0.95				-0.04	0.18	0.96
Extracurricular activities in science				-0.13	0.12	0.88				-0.15	0.15	0.86
Family Level Predictors												
Father education				0.02	0.08	1.02				0.02	0.09	1.02
Mother education				-0.01	0.07	0.98				-0.09	0.10	0.99
Relatives' major (STEM)				-0.08	0.19	0.92				-0.09	0.20	0.91
Family income				-0.07	0.09	0.93				-0.09	0.10	0.91
Family encouragement and support				0.38	0.18	1.47*				0.41	0.22	1.51*
Level-2												
Classroom Level Predictors												
Tracking (Science)							0.74	0.44	2.10	0.91	0.47	2.48
Science and math teachers' support							-0.05	0.31	0.95	-0.08	0.37	0.93
Interactive science and math lessons							1.28	0.27	3.58**	1.58	0.53	4.89**
Intraclass Correlation Coefficient (ICC)		0.18										
Log-Likelihood		-9.56			-9.38			-9.73			-9.55	

Note: * when p < 0.05; ** when p < 0.01; *** when p < 0.001

7.3 Discussion of key themes for RQ 3

7.3.1 Tracking: A negative trend

Based on the results above, it is significant to note that the frequently cited literature on the significant influence of the science track on STEM majors in higher education was not found to be significant in this study. This result is surprising since students in the science track are exposed to more science and mathematics subjects than their counterparts. Previous studies (e.g., Lichtenberger & George-Jackson, 2013; Lowinger & Song, 2017; Trusty, 2002; Wang, 2013) supported the stance that to boost upper secondary school students' interest in pursuing STEM majors, an earlier introduction and exposure to science and mathematics related courses could be one of the effective methods. However, reflected on the synthesized conceptual framework, the current study added to this battery of knowledge by revealing that bifurcating students into different tracks of science or social science is not significantly associated with their aspirations of STEM majors. Put simply, tracking—increasing the teaching and learning hours , as well as contents, to provide more time for students to be exposed to more science and mathematics courses—does not matter in the Cambodian upper secondary school context. As mentioned earlier, the keys differences between the two tracks are the number of teaching and learning hours and the amount of content to be covered, in science and mathematics subjects.

This finding sounds surprising, yet it tends to reflect the contextual reality in a few manners. First, although MoEYS bifurcates the tracking system, and students in the science track are exposed to more science and mathematics courses, the different in time are just two hours and one hour allocated to mathematics and science subjects per week between the science and social science tracks, respectively. While students in the social science track study mathematics for 3 hours and science subjects for 2 hours each week, students in the science track at traditional schools study 5 and 3 hours per week on mathematics and each science subject, respectively. The NGS have increased these amounts to 6 hours per week for mathematics and 4 hours each for science subjects (physics, chemistry, and biology). However, only 1 hour per week is allocated for earth-environmental science. Moreover, while not only the teaching contents but also how to effectively transfer those contents to students (teaching methods) embedded within the policy initiatives of several other countries that have implemented tracking systems (Marginson et al., 2013), the teachers and the teaching methods might not have been changed much in the context. Although there have been some improvements, the chalk and talk teaching method (teacher-centered) might still exist, especially in the rural parts of the country (World Bank, 2012).

Second, Cambodian students might not perceive track choice as a pathway to their choice of major in higher education, but merely for passing the baccalaureate examination. Since the grade 12th national examination was reformed in 2014, the proportion of students in the science track that passed the examination has reduced, while the percentage of students in the social science track has been gradually increasing (MoEYS, 2017; see Figure 7.1 for details). Consequently, the share of upper secondary school students who choose the social science track has gradually increased. The finding for research question one confirmed that most students chose the science or social science track, mainly because of their academic achievement in science and mathematics in particular, and their academic achievement in general. Since their performance was low and they wanted to pass the national examination, students tended to swing to the social science track, for which they do not need to take all science and difficult mathematics tests on the baccalaureate examination.

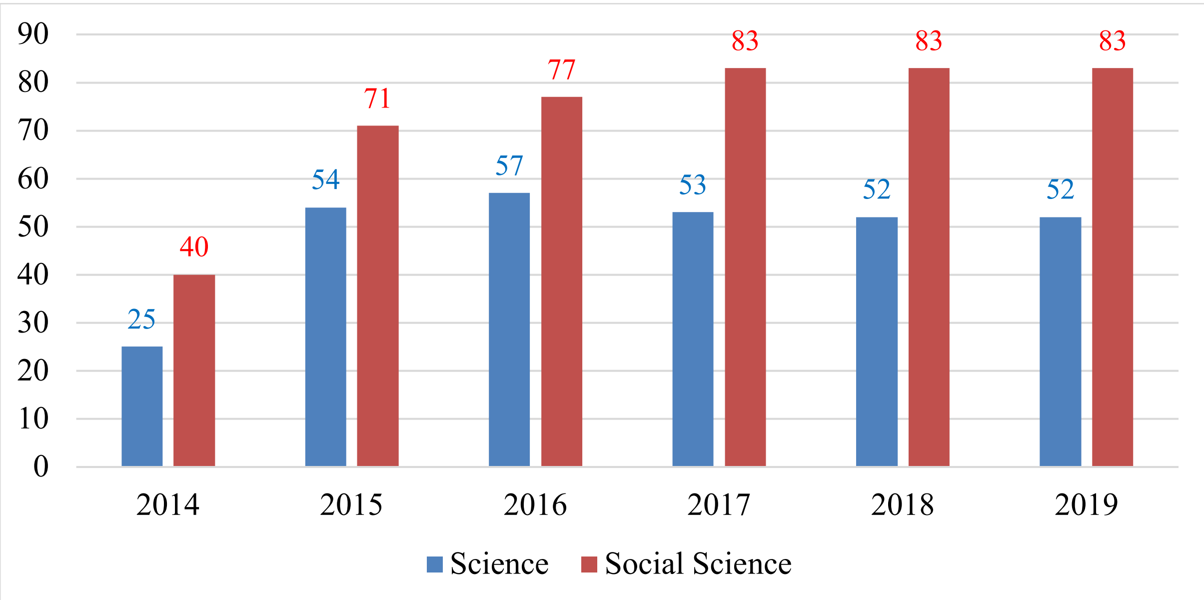


Figure 7.1: Percentage of grade 12th students passing the national examination by study track

7.3.2 Interactive science and mathematics lessons really matter

Adding on the extant knowledge, to enhance the choice of STEM majors, this study placed more emphasis on the effects of how science and mathematics lessons are taught, rather than solely on bifurcating students into science and social science classes (e.g., differentiating the number of hours spent studying and the focus of the content). The current findings aligned well with the conceptual framework, which stipulates that an individual's intention to enroll in a certain field of study (in this case, choosing a STEM major) is the consequence of the sequential cumulative effects of numerous learning experiences that students have gained during science and mathematics classes (Krumboltz, 1979; 1990; Maltese & Tai, 2011; Lent et al., 2002; Wang, 2013, 2017). Thus, given that there are a few differences between the science and social science tracks, the tracking system does not influence the choice of STEM or non-STEM majors in higher education if the teaching methods in science and mathematics classes does not change, maybe, to the ones that foster interactions between teachers and students.

As it is said that "poor teachers explain, excellent teachers elicit", the interactive lessons of science and mathematics accommodates enabling conditions to elicit ideas, and to inspire students' interests in the subject matter and trigger their intention to engage in related fields. Engaging students in active learning—pedagogical approaches that truly engage students intellectually and involve thinking, problem-solving, questioning, or analysing information—could improve their performance and lead them to pursue STEM (e.g., Graham et al., 2013; Lopatto, 2007; Wang & Lee, 2019). More exposure to science and mathematics content at upper secondary school might be important, but the most important thing is how interactive the science and mathematics content (discussed among teachers and students) is in the classroom setting. This finding was supported by what has been found that a learning process that is active or interactive (or student-centered pedagogies, such as collaborative learning) could increase students' uptake in STEM (e.g., Erdogan & Stuessy, 2015; Graham et al., 2013; Simon et al., 2015).

7.3.3 The gender gap still exists in STEM in higher education

Gender plays a key role in priorities when choosing one's academic major, particularly in STEM related (Eam et al., 2019; Eng & Szmodis, 2015; Evans, Chen, & Hudes, 2020; Kao & Shimizu, 2019; Kwak, 1993; Mattoo, 2013; Shim & Paik, 2014). Gender continues to be influential, with women less likely to pursue STEM than men. Consistently, this study discovered that the Cambodian upper secondary school female students who participated in this study were not likely to choose STEM majors in higher education. The effect was even more serious when classroom dimension variables were included. This finding might be explained by what Wiswall et al. (2014) suggested: that STEM majors are characterized as a "chilly environment" where females can feel unwelcome, and might see that STEM majors and careers as male-dominated fields. This result might extend the battery of knowledge on the relationship between gender and academic aspirations of STEM majors as it reflects the cultural reality of a developing context like Cambodia. Gender stereotypes still exert a significant influence on the decision-making process. As Eam et al. (2019) remarked, gender-based stereotypes make it difficult for female university students to see themselves as pursuing science or STEM majors since most of the general public (including parents) holds the culturally embedded perceptions that STEM fields conflict with being a woman and a scientist or engineer. Another reason might be the lack of teacher role models. Some teachers have a biased belief in female inferiority in mathematics and seemed to give lower scores to female students (Lowinger & Song, 2017). This might have long-term effects on female's attitudes towards mathematics and their aspirations of STEM majors.

7.3.4 Academic achievement still matters

Another of this study's key findings also corroborates the findings from both Western and non-Western contexts is the positive correlation between students' academic achievement—self-observation generalisation—in grade 11th and their aspirations of STEM majors at university. Similar results have been found in the Cambodian literature by Eng and Szmodis (2015), Kao and Shimizu (2019), and Eam et al. (2019) and in the other context, for example, Lowinger and Song (2017), Shim and Paik (2014), and Wang (2013). Together, these researchers have claimed that science and mathematics achievement play a significant role in one's choice of STEM majors in higher education. Further, this study confirmed that not only academic achievement in science and mathematics, but also overall academic achievement at the pre-university level could influence students' interest and positive attitudes towards STEM majors at the university level. Moreover, the findings support the four conceptual models that were employed in the current study, in which personal input (derived from academic achievement and attitudinal variables) has a significant influence (e.g., Wang & Lee, 2019; Lent et al., 2002). This is not surprising as STEM majors seem to be demanding, and students might need high academic achievement, especially prior to entering university (Eam et al., 2019; Kao & Shimizu, 2019). This finding might cause Cambodian students to believe that STEM is just for *"the brightest"* group of students. From this perspective, it is clear that to orientate the students towards STEM majors, the negative influences of myths and misconceptions should be addressed (Eam et al., 2019).

7.3.5 Attitudes towards science matter

Of the students' motivational attributes (attitudes towards science and mathematics, science and mathematics self-efficacy, and future plan in science), this study posited that future plan in science significantly influenced their choice of STEM major. This eflects the importance of student's motivational beliefs regarding their academic majors and future careers (Han et al., 2002; Shim & Paik, 2014; Wang, 2013). Those who had a clear plan in science at upper secondary school tended to have a higher probability of choosing a STEM major in higher education. This motivational belief might be one of the consequences of the academic achievement. A significant regression equation was found (F (1, 694) = 57.04, $p<.001$), with an $R^2 = .08$). Put simply, those who had stronger academic achievement tended to have a clearer plan for their future majors or clearer career prospects in science. This study further highlighted the importance of higher scores for future plan in science and STEM majors in higher education. This might represent a logical understanding that students who have higher academic achievement tend to have clearer future plan in science and are more likely to choose STEM majors. Those who have long-term academic plan are better prepared in science and mathematics so as to take on challenging fields of study such as STEM. The follow-up interviews also highlighted that when the students had a clear plan to pursue science in higher education, they tended to choose the science track, in which they could study and enhance their science and mathematics competence, and as consequent, ignited their aspirations of STEM majors.

7.3.6 The role of family encouragement and support in science

This study also justified that parents played a significant albeit role in students' choice of college major. Family encouragement and support exert significant influence on students' important life decisions, including their choice of academic majors, especially in science (Simpkins et al., 2015; Miller & Kimmel, 2012). Because of their culture, Cambodian students are prone to parental advice. This is particularly important when choosing one's majors, as parents are one of their main sources of academic and financial support (Bieri Buschor et al., 2014). Asian parents—especially those from low socio-economic status families—expect their children to choose STEM majors (Lowinger & Song, 2017), as they believe that STEM majors will lead them directly to the workforce, potentially reducing the opportunity costs associated with attending college, and offering high returns (Lichtenberger & George-Jackson, 2013; Shim & Paik, 2014). Contextually, most of the parents seemed to perceive that enrolling in a STEM majors might lead to permanent career pathways (i.e., to become a science teacher).

7.4 Concluding remarks

With the aim to investigate the effects of the tracking system and the other multi-dimensional variables on Cambodian upper secondary school students' aspirations of STEM majors through a multilevel analysis, from the data and available evidence discussed above, this study revealed that the total variation in the aspirations of STEM majors could be accounted for by which class each student was in. First, based on the classroom dimension, it was discovered that course-taking behaviour between the science and social science track at upper secondary school of Cambodia did not have any significant influence on the students' choice of STEM major; rather, their decision was influenced by how interactive science and mathematics lessons in different classes of each respective track were conducted. Moreover, from the individual and family dimensions, gender, academic achievement, future plan in science, and family encouragement and support played significant functions in Cambodian upper secondary school students' aspirations of STEM majors in higher education. Among these significant variables, from a theoretical and practical perspective, it is worthy to note that interactive science and mathematics lessons (active learning experiences) and future plan in science were the strongest predictors of Cambodian upper secondary school students' aspirations of STEM majors in higher education. In conclusion, it was not merely on what the tracking was but on how interactive science and mathematics lessons were conducted was found to be crucial for enhancing students' aspirations of STEM majors.

CHAPTER EIGHT: OVERALL DISCUSSION, CONCLUSION, AND IMPLICATIONS

The current study was conducted to answer the three research questions using an explanatory sequential mixed method approaches with repeated cross-sectional design. Consequently, the study conducted three main analyses for the three specific research questions. Analyzed the data wave by wave, the current study, therefore produced a considerable number of findings, yet they all boiled down to achieving one ultimate purpose: to understand students' choice of the science track, and the effects of tracking and the other multi-dimensional factors that influenced Cambodian upper secondary school students to transition from the science track to STEM majors in higher education. In this vein, this chapter first offers a brief summary of the key conclusions to each specific research question. Second, the chapter provides an overall discussion of the primary results for the main objective of the current study: the effects of tracking and other factors that influence Cambodian upper secondary school students' aspirations of STEM majors. The last part of the chapter is more practical in the way that it envisions some possible strategic implications towards promoting Cambodian upper secondary school students to transition from the science track into a STEM major in higher education.

8.1 Summary of all key findings for each specific question

The main purpose of the current study was to comprehend the students' choice of the science track at upper secondary school and the factors that correlated with their aspirations of STEM majors in higher education. To deeply understand the issues surrounding the aforementioned main purpose, the current study attempted to answer three specific research questions. The results could be concluded as follows:

- responding to *Research Question 1* on Cambodian upper secondary school students' choice of the science track, the study found that of the individual factors, performance in science subjects, attitudes towards science, and future plan to major in STEM affected students' choice of the science track. Moreover, students' engagement in their academic pursuits by spending more time self-studying at home—particularly science and mathematics subjects (chemistry and mathematics)—signified their likelihood of choosing the science track among Cambodian students. Reflecting on the cultural influence of family on academic choices, family encouragement and support (especially families with more educated mothers) contributed to the variance explaining students' choice of the science track.

- responding to *Research Question 2* on the trends and patterns of time-varying covariates, the study exhibited that the students scored highly on science and mathematics outcome expectations, science as a practical subject, and the importance of science in society. However, they scored at a moderate level on mathematics self-efficacy, science and mathematics self-concepts, interest in science at school, science activities outside school, extracurricular activities in science, future plan in science, support from science and mathematics teachers, and interactive science and mathematics lessons. There was no significant difference between males and females for most constructs. Notwithstanding, there was a significant difference between schools and study track. Simply said, schools in Kampong Cham tended to have a higher mean score on most of the constructs compared to schools in Phnom Penh and Battambang. Students from NGS tended to have higher scores than students from the other tracks. Across one academic year span, some constructs exhibited an increasing trend, while the others showed a decreasing trend. This varied according to the covariates of gender, school location, and study track.

- responding to *Research Question 3*, the main research question, on the effects of the tracking system and other variables on Cambodian upper secondary school students' aspirations of STEM majors in higher education, current study revealed that, based on the classroom dimension, course-taking behaviour between the science and social science tracks at upper secondary school in Cambodia did not have any significant influence on the students' choice of STEM majors. Rather, the students' aspirations were influenced by how interactive science and mathematics lessons in different classes of each respective track were conducted. Moreover, from the individual and family dimensions, gender, academic achievement, future plan in science, and family encouragement and support played significant roles in students' aspirations of STEM majors in higher education. This finding highlights the importance of not merely bifurcating upper secondary school students into different science or social science classes, but of how science and mathematics lessons (interactive lessons) in each respective track are conducted, of the individual attitudinal perspective, and of encouragement and support from one's family and school.

8.2 Discussion of key themes responding to the main research objective

Overall, in response to the main objective that sought to understand Cambodian upper secondary school students' track choice and its effect on students' aspirations of STEM majors in higher education, the study deduced that academic achievement and attitudinal variables contributed to the students' choice of the science track. Since a different track choice had small effects on enhancing students' academic achievement, as well as interactive science and mathematics subjects and attitudinal constructs, students were not likely to transition from the science track to STEM majors in higher education.

However, to draw a sound conclusion, the following questions should be discussed in relation to the context and empirical evidence. First, how truthful and reliable are these conclusions in the current context of Cambodian upper secondary school? How do the current findings fit into the literature and theoretical models on students' choice of STEM majors? How do these findings respond to the problem stated? What kinds of implications can be drawn from the study? The section that follows, therefore, closely examines and verifies these major questions.

8.2.1 The claims explaining science track choice among Cambodian students

Upper secondary school years have been considered as a critical period for attracting students to science-related majors in higher education and careers. For decades, concerns have increased among policy makers and researchers with respect to the decline in students' interest in science and their decision to study science worldwide. Therefore, this current study contributes to the scarce of knowledge particularly in the developing context, regarding the claims underlying the cause of the decline in students' interest in science. Based on statistical findings, corresponds to the study's main objective, the study argues that one's choice of track between science and the social science at upper secondary school is significantly influenced by academic performance in science and mathematics, attitudes towards science (science as a practical subject and interest in science at school), and family encouragement and support.

First, according to the results, a one-unit increase in performance in science subjects generates a change in students' choice of the science track by a factor of 2.81. This implies the significant effect of *performance in science and mathematics* on students' choice to the science track. The findings confirm what research has revealed in the other contexts: students' performance in science and mathematics, as well as overall academic performance, explains students' choice of track (Ayalon & Yogev, 1997; Dustmann, 2004; Paik & Shim, 2013). Students with high academic achievement are more likely to choose the science track over the humanities/social science. Although the students' choice of track is primarily based on individual preferences rather than academic performance, students in the science track generally have higher positive academic performance than their counterparts (Chen, 2013; Kinyota, 2013; Kwak, 1993; Li & Kuan, 2018; Myeong & Crawley, 1993; Paik & Shim, 2013).

Contextually, although students in the science and social science tracks take the same subjects, the focus is different. While the science track focuses on science and mathematics subjects, the social science track focuses on Khmer literature and social science subjects. Also, since students in the science track need to take science and mathematics subjects in the baccalaureate examination, those who chose the science track perceived themselves as having higher performance in these subjects, as well as their academic achievement. On the other continuum, those with lower performance in these subjects tended to switch from the science to the social science track, since they believed that it would be easy to get a "passing" grade on the examination. The qualitative interviews also support the conclusion that most students swing from the science track due to their perceived low performance in science and mathematics subjects. The students witnessed that the share of students in the science track who passed the examination in recent academic years was lower than that of students in the social science track.

Second, for the construct of attitudes towards science, the results exhibited that a one-unit increase in *science as a practical subject* produces a change in Cambodian upper secondary school students' choice of the science track by a factor of 2.07, and a one-unit increase in interest in science activities at school generates a change by a factor of 2.05 in one's choice of the science track. This finding is in line with the finding that science track members have higher positive scores for mathematics, science and general science self-concepts, and attitudes measures (Kinyota, 2013; Myeong & Crawley, 1993). For example, in one study, interest, appreciation, and self-confidence decreased for students who did not choose physics, while they did not for students who chose physics. Students' attitudes towards physics influenced their choice of subject (Stokking, 2000).

This finding posited to the stance that among the factors that had been lessening or swinging students from science was the lessening of their attitudes towards science and future participation in science. The present study's statistical findings revealed that the students had a low rating scale for attitudes towards science sub-constructs. In this regard, the declining trend of Cambodian upper secondary school students' interest in science might be explained by the low attitudes towards science. That said, why do attitudes towards science matter? The qualitative interviews explained that students did not like science, as it is hard and complex. Most of the students interviewed argued that to do well in science, they needed to work hard and spend a considerable amount of time and money on "private classes" to strengthen their abilities. However, because they were "lazy" and they had a financial burden, the students tended to recount their attitudes towards science when choosing a track.

Third, from the family dimension, it was revealed that a one-unit increase in *family encouragement and support* in science generates a change in students' choice of the science track by a factor of 1.61. Parents' influence was stronger for the science track than for the social science track. If parents favour the social science track, they might not force their children to comply with their wishes. However, if parents favour the science track, they might be more determined for their children to choose the science track (Myeong & Crawley, 1993). Consistent with prior studies (e.g., Simpkins et al., 2015; Shin et al., 2015), the current study revealed that family environment tended to be a significant untapped resource of support for students.

For example, parents' provision of enriching experiences at home, such as playing mathematics games, hobbies, science activities, and encouragement to take science and complete science homework for example, were central to students' interest in science, knowledge, and skills. Family encouragement culture is a motivating factor in students' persistence to study science, since it is related to the quality of family interactions, which are intrinsically focused on or emphasize mastery goals. The encouragement and support in this manner, from the follow-up interviews, showed that not only spiritual encouragement and social networks, but also financial and physical support, from one's family are important. Further, students in the science track stressed that they needed to take private classes in science and mathematics subjects. As mentioned earlier, students in the science track have to take mathematics and all science subjects on the examination. To strengthen their academic competence, they need to take private tutoring. However, students in the social science track do not spend much on private tutoring, as they take only social science subjects, which are based on rote learning. Thus, students in the science track need more financial support from their families than students in the social science track.

While the purpose of bifurcating track choice is to guide students toward the science and social science track in higher education, *future plan in science* was not a significant predictor in their decision-making process. This result is surprising, yet reflects the qualitative results in a few perspectives. First, some respondents reported that when choosing a track, they do not receive any orientation on what the consequences of that choice are. For example, even though about 80% of the respondents said that they have received information on their track choice, the information did not cover what kind of major to pursue when choosing a particular track at upper secondary school.

Though according to MoEYS (2004), students should be oriented on their academic and career track, the interviewees mentioned that they did not make a well-informed choice regarding their selected track at upper secondary school, since they did not receive much advice on majors in higher education, which would be the consequence of track selection. From a second perspective, some students felt that choosing the science track would merely provide them an open pathway/open choice for selecting a major in higher education. Simply said, the students chose the science track because they wanted to build their background competence so that they could choose to study either the science-related or social science-related fields upon entering higher education. However, if they choose the social science track, they might pursue the social science-related field in higher education. In addition, unclear future plan (or even blind choice) is also a big concern among Cambodian students. As explained, students had lower future plan let alone a clear plan in science. Their track choice of science or the social science was merely for their short-term goals of passing the grade 12^{th} national examination.

8.2.2 The effects of different tracks on time-varying covariates

For decades, studies have investigated the various effects of science-focused schools on students' learning outcomes, compared to their counterparts in traditional or non-science-focused schools. Studies found that science-focused schools have a significant effects on students' learning outcomes (Judson, 2014; Tofel-Grehl & Callahan, 2014; Wiswall et al., 2014). The section below discusses how choosing different tracks enhanced the constructs that influenced the students' choice of track (elaborated in the first section) and predicted their aspirations of STEM majors (addressed in the later section).

First, from academic achievement perspective, different track had a small effect (*Cohen's d* =.25) on *performance in science and mathematics* subjects, which varied significantly between students in NGS, in the science track, and in the social science track. The finding is consistent with the general characteristics of the so-called STEM-focused schools, whose students outperformed their counterparts in traditional schools on mathematics and reading tests (Becker & Park, 2011; Bicer et al., 2015; Bicer et al., 2018; Han et al., 2016; Judson, 2014; Mean et al., 2016; Morrison et al., 2015; Scott, 2012). Moreover, the examination of estimated marginal means indicated that while performance in science and mathematics among students in the social science and science tracks exhibited a slight increase, students from NGS showed a slight decrease in their performance from grades 10th to 11th. This is interesting and reflects the conditions of NGS. Students in NGS need to take more mathematics and science classes with inquiry or project-based instruction, which could enhance their performance in the subject. Moreover, students in NGS have higher science and mathematics self-efficacy than students in the traditional schools.

Second, different tracks also had a small effect (*Cohen's d =.07*) on *science as a practical subject* (a construct of attitudes towards science) from observations 1 to 2. The estimated marginal means indicated a slight decrease in the perceived practical work in science class among students in the NGS and in the science track. This finding is in line with other studies (e.g., Chonkaew et al., 2016; George, 2006; OECD, 2016; Simpson & Oliver, 1990) that found that attitudes towards science generally declined throughout middle and high school. This phenomenon might, in part, be due to a lack of teachers' knowledge regarding science lab implementation. Teachers are not aware of STEM concept (MoEYS, 2018h). Although recent advancements in teacher training facilities have started to incorporate professional development for pre-service teachers, limited science equipment and resources are available at all upper secondary schools (Eng & Szmodis, 2015; CDRI, 2015). The qualitative interviews highlighted the concerning issue of the less frequent of science experiments in science classes in Cambodia's upper secondary school. The respondents further explained that there are only a few experiments, mainly in chemistry subject. Sometimes the room (a resource center in the so-called resource schools) in which the students can conduct experiments is not available. The availability of equipment is also a big concern. Students said that sometimes, they cannot carry out experiments because they do not have enough equipment to match with the lessons.

Third, different track had a *negative* effect on enhancing students *future plan in science* but a medium, negative trajectory in the second observation. Simply put, despite choosing the science track at upper secondary school, students' interest in pursuing science in higher education is decreasing. This is surprising, as students who are exposed to more science and mathematics classes are more likely to have higher participation in science or STEM in higher education. However, this study found a contrasting trend. Being in the science track and exposed to more science and mathematics lessons tended to reduce students' future plan in science. The estimated marginal means revealed an even more unusual trend. Students in the science track as well as students in NGS exhibited a negative trajectory for future plan in science. This is even more alarming, since NGS are aimed to also promote students' interest in STEM majors in higher education. Their future plans in science also indicated a negative trajectory.

Next, different tracks had different effects on perceived *interactive science and mathematics lessons*. The estimated marginal means signalled that students in NGS outperformed students in the science and social science tracks in both the first and second observations. However, there was a decreasing trend for students in NGS, while the trend remained stable for students in the science and social science tracks. This finding also confirmed that attending a STEM-focused school enhanced interactive science and mathematics lessons compared to counterpart schools. Teachers in STEM-focused schools are encouraged to implement interactive teaching and learning methods in the classrooms, including project-based learning, inquiry-based learning involving STEM teaching, and real-world STEM experiences (Bicer et al., 2015; Mean et al., 2016). Seemingly, inquiry and thinking are highly valued and discussed in specialized STEM schools, but inquiry-based learning as a form of pedagogy varies greatly in implementation across schools and disciplines. Teachers and students developed strong social interactions through group work, small school relationships, and peer teaching and learning, leading to higher learning outcomes in STEM-focused schools (Morrison et al., 2015). By contrast, the declining trend in the second observation may have been due to the fact that most teachers still employ traditional teaching method of teacher-centered (Sar, 2014; World Bank, 2012). Students might also be familiar with the interactive instruction and rated relatively modest in second observation. The qualitative results highlighted that science and mathematics teachers mostly use one-way teaching in traditional school, as in the example where a student explained that a teacher provided some explanations and asked the students to do practice exercises in the coursebook. Also, there was little time where students discussed the applicability of the content in a real-life context. Mostly, the lessons were exercise driven. Furthermore, there was no interaction effect between the tracking system and the two observations for interactive science and mathematics lessons.

Last, of the contextual support in the STEM transfer model (*family encouragement and support*) students from different tracks also perceived different levels of support and encouragement from their families in pursuing science. Students from NGS had more support than those in the science and social science tracks. The estimated marginal means also indicated that NGS students tended to have higher encouragement and support from their families than students in the science and social science tracks in both the first and second observations. This finding reflects the context of NGS and the science track in a few manners. First, according to NGS guidelines (as it becomes autonomous), students need to pay a contribution fee to support the school's operation. Thus, family plays a big role in providing financial support to students. Second, strong encouragement and support from one's family is needed since students spend both time and money to participate in extracurricular activities in science (such as science fairs and science competitions) as well as to study full-time and to complete projects. Students in NGS participated in more extracurricular activities in science than students in the science and social science tracks ($F = 31.29, p < .001$, Eta square = .08).

8.2.3 What matters most in students' aspirations of STEM majors

The effects of tracking on students' choice of major in general and on STEM in particular has also been a quest among researchers for decades. In contributing to the debate on the effects of different tracks and other multi-dimensional factors on students' choice of STEM majors, the findings from the current study could be explained as follows.

First, the study posited that there was no association between *tracking* between science and the social science on students' aspirations of STEM majors in higher education. Students in the science track were not mainly orientated toward STEM majors, but tended to switch to non-STEM majors. Current findings contradict the results of prior studies (e.g., Kinyota, 2013; Li & Kuan, 2018; Myeong & Crawley, 1993; Paik & Shim, 2013; Shim & Paik, 2014). However, it was also confirmed recent studies (e.g., Darolia et al., 2019; Maltese & Tai, 2011; Wiswall et al., 2014). This finding sounds surprising, yet reflects the contextual reality in a few manners. First, although the ministry bifurcated the tracking system, and students in the science track are exposed to more science and mathematics courses, there are just two-hour and one-hour differences allocated to mathematics and each science subjects per week between the science and social science tracks, respectively. Moreover, while not only teaching contents but also how to effectively transfer those contents to students (teaching methods) is embedded in the policy initiatives of the several countries that have tracking systems (Marginson et al., 2013). As such, the teachers and teaching methods might not change much in the context involved. Inquiry is not used by primary (MoEYS, 2019b) and traditional upper secondary school science teachers, who tend to be more teacher-centered (Sar, 2014; World Bank, 2012). Most of note, based on the *partial eta-squared* effect size presented in the patterns of time-varying covariates, choosing a different track had a small effect on enhancing the constructs of the STEM transfer model. Statistically speaking, the effect size ranged from a partial eta square of .02 to .22, which indicated small to medium effects. More seriously, across the two observations, tracking did not have any significant impact on interactive science and mathematics lessons. This means that the level of interactive science and mathematics lessons was not significantly different regardless of the tracks—science and the social science track—the students attended $F(1,697) = .706$, $p > 0.05$.

Second, as discussed in the chapter on Finding III, *academic achievement* was among the most influential factors influencing students' aspirations of post-secondary STEM majors. Statistical findings revealed that a one-unit change in academic achievement generates a factor of 1.44 in the students' aspirations of STEM majors in higher education. This implies that students who have achieved well in general (and in science and mathematics in particular) are more likely to choose STEM. Statistically speaking, the performance of the students who were more likely to choose STEM was higher ($M = 2.79$) than those who chose a non-STEM major ($M = 2.28$; $t = -8.99$, $p < 0.001$). This finding also confirmed that students tend to pursue STEM majors if they believe that math and/or science is among their high-achieving subjects (Eng & Szmodis, 2015). However, from the trends of the time-varying covariates, the mean score of academic achievement among Cambodian students was just average ($M = 2.50$). Specifically, the trends also revealed that there was variation in science and mathematics performance across schools and study tracks. However, since different tracks had small effects on enhancing the students' academic performance in general, and science and mathematics in particular (*t* = *-6.71, p* < 0.001*, ES* = *.25 [small effect]*), the probability of students transitioning from the science track to STEM majors in higher education was also low.

Third, the effect of *interactive science and mathematics lesson*s on students' aspirations of STEM majors is critical. Students' perceptions of science instruction (what teachers performed in the classroom) significantly influenced their attitudes towards science, which in turn influenced their academic achievement. Since science instructions that included regular laboratory experience engaged students in the learning process of active or interactive (or student-centered) pedagogies, which had a positive significant influence on the students' attitudes towards, and their achievement in science (Freedman, 1997), as well as their uptake in STEM majors (Erdogan & Stuessy, 2015; Graham et al., 2013; Simon et al., 2015).

From investigating the effect of tracking on interactive science and mathematics lessons, it was revealed that Cambodian upper secondary school students only perceived an average level of interaction during their science and mathematics classes; this level did not change across the two observations as a function of study track. During the follow-up discussion, the respondents (especially those from traditional upper secondary schools) reported that their science and mathematics teachers usually employed a one-way (teacher-centered) method where teachers merely explain the lesson, and ask students to do the follow-up exercises in the course book. There were some exceptions in the NGS, where students experienced the project-based or problem-based learning method, yet this was in small scale. Thus far, there are only 11 NGS across the country, among which 7 are at the upper secondary school level.

Fourth, based on the family dimension, the effect of *family encouragement and support* also significantly influenced Cambodian students' aspirations of STEM majors in post-secondary education. This finding corroborates the stance that students have higher interests in STEM if they perceived their parents to value STEM disciplines (Eng & Szmodis, 2015). Parents played an important role in students' interest in STEM education, and parents' support seemed to have a greater influence on STEM interests compared to that of teachers' support in science. There was an influence of parental encouragement of science and mathematics during the secondary school years. This was particularly influential for highly educated parents. When children of highly educated parents cannot understand concepts or problems, they can ask their parents to help (Miller & Kimmel, 2012). However, in the context, parents seemed to value or encourage their children to choose a business or social science major, rather than a science or STEM-related one. As Eng and Szmodis (2015) highlighted, many parents and students do not see the value of science majors when exploring profitable and prestigious career options. Therefore, as parents tended to favour the social science over science-related fields, they would give less encouragement and support to their children to choose STEM as their major. This phenomenon was larger for female students, who face stereotypes in choosing non-STEM fields, as their parents perceived that STEM majors and careers are male-dominated.

8.2.4 Talking about leaving: Why do science track students leave STEM?

In addition to the quantitative results, follow-up interviews to gain insight understanding into the influential factors were conducted. Therefore, this sub-section summarizes the synthesis of the reasons given by switchers and non-switchers to the question, "Why did you/did you not choose a STEM major"? Their answers were grouped into 7 themes, shown as *"Reasons given"* in Table 8.1 and were described below.

Table 8.1: Reasons science track students gave for pursuing STEM or switching to non-STEM

Reasons Given	Number of times reported		Interviewees' remarks
	Non-Switcher	Switcher	
Open choice	5(20%)	8(32%)	- The reason I chose science track was because I wanted to build my background in science and mathematics. I will stay in science or I can switch to social science related. I also like science, but I am better at social science. I did not choose social science track at upper secondary school because if I chose social science, I could not pursue science later. However, if I chose science I can either pursue science or social science in higher education. I like mathematics and science, but it is just for open choice for me. *(S639)* - I chose science track because I could find more jobs either in science or in social science fields. It is more open. For example, if I choose science track I can either major in doctor, engineer, or other social science fields. *(S675)*
Performance in science and/or mathematics	13(52%)	8(32%)	- First, I was interested in science, but I dropped because I was a slow learner. I could not do well in mathematics. For social science track, I could study

			Khmer quickly so I am sure I could pass the national exam at a higher rate than if I was in the science class. First, I just want to test my ability in science and see if I could make it or not compared with other students. Then I observed that I could not do it. Science track students perform better than those from the social science track. *(S655)* - I choose science because I like it. I could catch up with science and mathematics more than in social science since I was in primary school. I am particularly good at chemistry. When I moved to grade 10th, I have been good at chemistry, it was just like when I was in grade 9th. And because I had good background in chemistry from early grade, when I moved to grade 10th, my chemistry was even better. However, I performed poorly in social science subjects. *(S671)*
Future plan in science	10(40%)	11(44%)	- When students chose the science track, they aimed for only passing the examination not for the major at university. In our country it is not the same as the other countries whereby students are not clearly explained about the university majors (this major is like this and that major is like that) so that students could clearly decide which one should be good for them. By grade 10th, our students are asked to choose the study track, and they do not know what to base upon, then their decision was based on the difficulty in the examination not because on their personal interest and clearer long-term academic plan. *(S319)* - To increase the students' interest, it is important to know why they are interested in particular major or is it because of their talent. To me, I choose science because I like science since I was young. I like to do research. Then, I only focus on science subjects more than social science. I like it because in the future I want to work in science related sector. *(S302)*
Gender stereotypes	5(20%)	5(20%)	- To me, I do not like science because I think that science subjects are laboratory-related, and I do not like that kind of working environment, where we work with paper and pen. And this is not the stereotypes of female careers. *(S319)* - I feel that my parents will not advise their children, female like me, to major in STEM-related as they believe that I will be lonely because these majors are male-dominated. *(S298)*
Interactive science and mathematics lessons	12(48%)	8(32%)	- When he [my science teacher] arrived, he explained and give exercises to the students, but his explanation was usually a one-way communication. Sometimes, since he asked students to answer, some of us just

			answered quietly followed after the teacher. The classroom activities were not so interactive. Students just sat and listened to the teacher. There were about 4 or 5 students in the class answered, and if we talked about group work (student-centered approach) used in the class, I would say it is seldom. *(S428)* - First, I was thinking of studying international relations, but when I experienced with a lot of interactions through experiments in science class, my thoughts changed a lot. I enjoy learning about science and feel that it is easy. Before I thought that it was difficult since it involves with complex formulas, but now I feel that it is much easier than the social science related fields. Then I changed to telecommunications. *(S298)*
Practicality of science	8(32%)	8(32%)	- I feel that learning nowadays is true to some extent and cheat to some other extent. We do not know how to apply knowledge. Sometimes, learning the point is just for the sake of learning. However, some other points, when teachers explained and demonstrated us their applications through experiment, we just felt that oh… it is so… and we are interested. (*S267)* - Learning at NGS has changed the way I perceive science. I could know that science is not just about learning based on memorizing, but it needs research. Before I was poor at science, I could only do some simple exercises; I do not know how to apply the knowledge in real world, but when I come here [NGS], I know that we could apply this concept in this and that concept in that, and it changes my mind to be interested in science and I pursued science. *(S284)* - NGS has more capacity to interest students into science because at NGS there are project and research work which enable the students to know more about the concepts that we are learning in class. Though there are some practices (experiments), there should be more. Also, there should be more explanation on how the lessons we learnt in class could be applied in our daily life (its importance) so that the students see the values of learning and feel curios more about science. *(S319)*
Family encouragement and support	13(52%)	4(16%)	- The encouragement and support in science from my family is almost zero. My parents do not know much about science, so they never do anything to encourage me to do science. My dad could support me (help me with science lessons or assignment) only up to grade 9^{th}. He could not help me with the lessons or exercises in any later grades. *(S319)* - One more thing is parents. Since parents, especially older ones, were not trained about science and

			technology, and then they do not know much about how important science is in their real lives. Thus, when seeing their children (like us) choose science, they feel that it is opposite to their thoughts. Another, to study in science class, it needs a lot of support from parents, both time and money. *(S284)* - First, I chose non-STEM but then I switched to STEM-related fields because my family supported me. They advised me to choose medicine. Because my sister has gone to work in South Korea, she could financially support me for my study in medicine, which requires to spend much more. Then, my family encouraged me to pursue medicine. *(S647)*

As a synthesis of the qualitative findings from the follow-up interviews to further explain the quantitative results, students switched from or pursued STEM majors when they transitioned from the science track into higher education. These changes were explained by open choice, performance in science and/or mathematics, future plan in science, gender stereotypes, interactive science and mathematics lessons, the practicality of science, and family encouragement and support.

Open choice: Students who chose the science track and switched to non-STEM majors in higher education explained that their science track choice was just an open choice. First, enrolling in the science track was meant to enhance their performance not only in science and mathematics, but also in social science subjects. Students in the science track focused more on the difficult subjects of science and mathematics and, as they stated, memorized-based social science subjects. If they chose the social science track, they could focus primarily on social science subjects and milder science subjects. However, when they recognized that their performance in high level science subjects was not sufficient, they switched to a non-STEM field. Second, science track students could choose to pursue either in STEM or non-STEM majors, but not vice versa. Simply explain, science track students could pursue STEM or switch to a non-STEM field, but it would be hard for social science track students to switch to STEM.

Performance in science and/or mathematics: The interviewees also highlighted that their aspirations to pursue STEM or switch to non-STEM fields contributed very much to their performance in science and/or mathematics. Students who were initially interested in science majors and decided to switch to non-science fields acknowledged that their upper secondary school mathematics and/or science performance was not adequate. In the very early stages, they expressed that they would not even pass these subjects on the strict national examination. In contrast, science track students who perceived that their performance in science and mathematics was adequate to not only pass the national examination, but also to pursue science-related majors in higher education, would pursue STEM. This perceived performance triggered their interest in science and as a result their desire to pursue STEM. However, some students tended to have lower performance in science and/or mathematics ($M = 2.5$, $SD = .77$), and hence, most of them switched to non-STEM fields.

Future plan in science: Non-switchers explained that their clear plan in science from early grades contributed to their choice of a STEM major. Let us examine two perspectives. First, the development of future plan in science stems from personal interest in science. Students expressed that their early interest shaped their plan for their major and career. Second, based on their plan, they tried to enhance their academic performance in science and mathematics subjects. Since this was grounded in their interests, their performance in these subjects was better than those who did not have the same level of interest. Consistently, under this theme, switchers from STEM majors described the *uninformed choice* as an explaining factor. They were not informed about the association between the science track choice and their plan for higher education. Thus, many non-switchers had built their choice of a STEM major on a long-standing aspiration and had expanded their knowledge and experiences in pursuit of these goals. Yet, leaving STEM might be caused by the negative trajectory of students' future plan in science from the first to the second observations ($t = 4.14$, $p < 0.001$).

Gender stereotypes: Female switchers reported that their choices were mainly based on two reasons. First, the characteristics of STEM majors. Most female students perceived that STEM careers are laboratory-related and did not like the perceived outside office environment surrounded by males. This is supported by the term "*chilly environment*" where females feel unwelcome. Second, following in their family's footsteps was reported to be the norm, especially for women. Switchers raised that their parents often viewed science-based majors as difficult for daughters. Being in science requires a lot of difficult science subjects at school and on the examination. Also, the working environment is inconvenient for females, as STEM careers are perceived to be male-dominated. However, it is interesting to note that female students who could discuss all of these issues with their parents and could ensure that they have strong self-efficacy to take science or STEM majors tended to pursue their personal interest, rather than be influenced by their parents.

Interactive science and mathematics lessons: Upper secondary school teachers of science and mathematics were influential in students' choice of STEM from several perspectives, one of which was their method of developing a strong interest in science and mathematics. Under this theme, several switchers from STEM explained that they could not understand their teacher's explanations. They tended to use more teacher-centered methodology. As a consequence, the students tended to have low performance in the subject and switch to non-STEM fields. In contrast, non-switchers explained that their teachers had more capacity to interest the students in science by employing experiments, group work, research, presentations, and other interactive activities that can enhance the students' interest and curiosity to know more about the concepts they are learning about in class. However, as discovered in this study, the level of interactive science and mathematics lessons was not significantly different between the science and social science tracks across one academic year span ($F = .35$, $p > 0.05$). This might contribute to the trend of students leaving the science track and STEM major.

The practicality of science: Non-switchers explained that their interest in science was ignited by visualizing its real application in society. Students could know that science is not just about learning by memorizing but needs research. It is not just about the ability to do simple exercises, but applying knowledge in the real world, which changed their minds such that they became interested in science and wished to pursue it. Because the school (NGS) has the equipment, teachers can conduct experiments and the students can see that science is practical, realistic, and they learn it. When students can visualize its application, it inspired them, and they became more curious. In contrast, switchers reported that when they only learnt the theory; they were not sure whether what the teacher was talking about was true or not. Contextually, it was found that, overall, there was no significant increase in the sub-construct of science as a practical subject from the first observation to the second observation ($t = -1.90$, $p > .05$).

Family encouragement and support: Under this theme, non-switchers commonly stated that they chose STEM partially because their parents or relatives work in STEM fields. Such networks might provide students with emotional support that they would have a secured career in the future. This is supported by the concept of *khsae* (string or network in Khmer) by Poeu (2017). Support for a family career trend was thus mentioned by upper students who stayed in STEM. Second, it was explained that to do well in science, students need both financial and academic support from their families. In the beginning, they need to spend more time and money on private classes in science and mathematics subjects to enhance their academic performance. In the later stages, they need to spend more time and money when taking science-related majors in higher education. Moreover, parents can help students with homework or assignments in science subjects. However, students, especially females, tend to have less encouragement and support to pursue science.

8.3 Conclusion

The present study was conducted in response to the declining trend of science track students and the association between the science track at upper secondary school with students' aspirations of STEM majors in higher education, and the limited number of graduates in this field to feed the labour market demand for the Royal Government of Cambodia's new trend of economic development during Industrial 4.0. Conceptually, the study contributes to the lack of knowledge, particularly in the developing contexts. While procedurally answering the three specific research questions, the current study' ultimate purpose was to objectively comprehend the relationship between Cambodian upper secondary school students' aspirations of STEM majors in higher education and other multi-dimensional factors that explain their aspirations. Several conclusions can be drawn based on the data analyzed and the results discussed. One of the conclusions was that individual academic ability and attitudinal variables and family encouragement and support play crucial roles in students' choice of the science track at upper secondary school and their aspirations of STEM majors in higher education. Another conclusion was that attending in a different track at the upper secondary level has an influence (yet with a small effect) on enhancing students' transition into STEM majors in post-secondary education. A third conclusion was that tracking into science or the social science at upper secondary school does not have any significant association with the students' aspirations of STEM majors in higher education, but their aspirations are influenced by how interactive science and mathematics lessons are conducted in each study track.

First, individual ability and attitudinal variables and family encouragement and support play crucial roles in students' choice of the science track at upper secondary school and their aspirations of STEM majors in higher education. Students' performance in science subjects and attitudes towards science (the practicality of science subjects [facts and fun] and self-interest in science at school) influence students' choice of science track. Students' engagement in their academic pursuits by spending more time self-studying at home (particularly in chemistry and mathematics) signifies the likelihood of choosing the science track. From the family dimension, reflecting the cultural influence of one's family on students' choice of science track, in terms of family encouragement and support in science, the unique cultural influence in Asian families (especially with higher educated mothers) contributes to the variance explaining students' choice of the science track. As Miller and Kimmel (2012) indicated, this influence is higher for students with better educated parents, who might help their children with homework or tasks that students do not understand or cannot complete. The results contribute to the knowledge that the worrisome declining trend of Cambodian students in the science track is due not only to individual academic ability and attitudinal variables, but also to cultural influence from one's family and the conditions of upper secondary school.

Second, attending in science track in traditional upper secondary schools and NGS or the social science track has an influence (yet with *small effects*) on enhancing the constructs that influence students' choice of track; this could encourage students to transition into a STEM major in higher education. Students tended to value the importance of science and technology in society but had low future plan to participate in science. This was very critical, as when they moved up through the grade levels (the difference between the first and second observations), their future plan to participate in science orbited in a negative trajectory. A closer examination indicated the possible effect of their performance in science and mathematics and their self-concept in doing science. Further, it is crucial to note that students chose the social science track were directed to only pass the national examination since they did not have to take science subjects for the examination. Some students from the science track in both traditional schools and NGS uncovered that their science track choice was just for an "*open choice*" for them. Simply put, they *did not make any well-informed decisions* on what to pursue in higher education when choosing each track to study. They choose science because it provided them with more choices of majors in higher education. In this regard, as attending in different track had a small effect in igniting students' interest to pursue science in the future, it might lead them to swing from science in higher education. The trend is more considerate for female students. As they move up through the grade levels, the effect becomes more of a disadvantage for them. Therefore, although there were some effects of different tracks across one academic year, the effects were small (effect size ranging from a *partial eta-squared* =.01 to .10). The effect was in a negative trajectory, particularly for future participation in science. More critically, there was *no effect* on interactive science and mathematics lessons.

Third, tracking into science or the social science at upper secondary school did not have any significant association with students' aspirations of STEM majors in higher education, but the aspirations were influenced by how interactive science and mathematics lessons were conducted in each track. From the HLM analysis, this study found that the total variation in choice of STEM majors can be accounted for by which class each student was in. Practices in different classes would have different effects on students' aspirations. This study also provides insight whereby variables from the individual and family dimensions continued to contribute to the students' aspirations of STEM majors. From a theoretical and practical angle, the interactive science and mathematics lessons, clearer future plan in science, stronger family encouragement and support in science, and academic achievement were the strongest predictors of Cambodian upper secondary school students' aspirations of STEM majors. Interactive science and mathematics lessons encompassing inquiry and problem-based teaching practices evoked the students' curiosity about science.

Clearer future plan in science provides a good foundation for the students to build their competence and to prepare to take more science. With clearer plan, students might be more prepared to achieve their plans, which could be impacted by the effect of the family engagement and support for children's academic endeavour. As Mullen (2011) indicated, parents might be an untapped resource for students not only in economic terms, but also for the sociocultural aspects of doing well in science at upper secondary school and their transition into STEM in higher education. Overall, these findings, although not conclusive, rather indicative—suggest that a higher level of interaction between teachers and students during science and mathematics lessons could enhance the students' academic achievement in, and attitudes towards science, and ignite their interest in STEM. This evidence underscores the need for science and mathematics teachers to change the norms of teaching, and to be aware of their role in providing support and encouragement for students to follow in their footsteps.

All in all, individual ability and attitudinal variables largely contributed to the students' choice of the science track. However, since participating in different tracks for one academic year had a small effect on enhancing students' academic achievement, as well as interactive science and mathematics subjects and individual attitudinal constructs, tracking was not significantly associated with Cambodian upper secondary school students' aspirations of STEM majors in higher education. Instead, the aspirations of STEM majors were significantly influenced by how interactive science and mathematics lessons were conducted in each track.

8.4 Implications

Current study has also thrown practical implications for increasing the likelihood of students choosing the science track, as well as the effect of science track on enhancing students' aspirations of STEM majors in higher education. First, to increase the probability of students choosing science in the school environment, *science and mathematics teachers* can learn practical lessons about how to attract individual students to science track. Teachers need to realize that, in addition to boosting students' academic performance through their teaching practices, one of their ultimate missions is to inspire and enhance students (especially females) such that they improve their science self-concept. Science and mathematics teachers must not only convey scientific knowledge to students, but also put in time and effort to model and inspire them to pursue science through addressing personal beliefs associated with choosing science and the culture of discussing its importance. Also, because the practicality of science subjects matters in science track choice, the most significant change is framing the presentation of the material to make science and mathematics lessons (especially from early grades onward) more practical, interactive, and realistic for students. Furthermore, teachers should make science and mathematics learning active. Since there are limited resources, "active" in this concept might not only imply doing more experiments, but also engaging students in a mixed learning activity where they can actively investigate the world around them. This process should start in the early grades. This could be done by strengthening students' academic performance and practical work in science. Also, it is critical to provide guidance on track choice selections at upper secondary school and how it affects one's future major and career.

Students need to have clearer plans and stronger self-concepts in taking science. They should receive guidance on how their decision related to their future major as early as possible.

Instead of having low self-concepts in science and mathematics, *students* should have a well-informed plan for their academic endeavour and believe in themselves. This highlights the crucial significance of family cultural influence. First, *parents* could engage in many school-related tasks to enhance their children's science performance and to motivate them to take science classes. This process does not require parents to be experts in science to help their children complete homework or to earn high scores in school. Rather, they could simply ensure that their children have enough financial support, time, and physical space to complete their homework and projects, as well as to self-study science and mathematics, and talk to them about how their science class are going. Other meaningful activities include creating a home environment for watching science shows, bringing children to museums or exposing them to natural phenomena, and talking about current events linked to the importance of doing well in science. These would be effective ways to inspire students, enhance their attitude, and interest them in taking science course at school. Interventions should also take parents' education into consideration. Also, any policy initiative to increase the share of enrolment in the science track should take geographic differences into consideration. Priority should be given more to schools in the rural parts of the country. This could be done by increasing not only the quantity but also the quality of science teaching, as well as other enabling conditions and support.

Second, it is necessary to reinforce upper secondary schools to be effective in increasing the level of constructs in the STEM transfer model, which can ultimately lead to higher levels of participation among student as STEM majors in higher education. First, the teaching approaches are the norms of the school (problem-based or inquiry-based methods) that create opportunities for students to engage in classroom activities. Perhaps such approaches can be implemented and supported not only in traditional schools, but also enhanced by NGS to strengthen students' academic outcomes and participation in STEM. Therefore, *science educators* (especially at the upper secondary school level) should emphasize the practical application of science. More efforts should be put into students learning from the primary to secondary levels; the emphasis should be on the application of knowledge and skills in real-life situations, particularly in terms of reading and mathematics problem-solving skills, rather than simply the content of textbooks. Teachers should require students to understand the contents and to be able to practically apply it to real-life situations and work scenarios.

Moreover, extending the practice of NGS or the teaching practices of its kind in enhancing students' attitudes towards (and engagement in) science and mathematics should also be an effective measure in promoting the constructs and encouraging students' trajectories in science towards the STEM nexus. Therefore, the plan to expand the scope to 100 NGS by 2022, and the resource upper secondary school with more active or interactive pedagogies, should be given high priority. In addition, science and mathematics teachers should play an important role (apart from their delivering interactive science and mathematics lessons); they should be role models in fostering students' attitudes towards (and supporting their interests in) science, helping them to learn both inside and outside the classrooms to increase their future participation in science. Also, the implementation of extracurricular activities should be made applicable nationwide and throughout the academic year. Moreover, *family encouragement and support* should play a critical role. Some meaningful activities would be creating a science environment outside school such as watching science shows, bringing students to museums or exposing them to natural phenomena, and talking about current events regarding the importance of doing well in science.

Third, the results of this study make a convincing case for enhancing students' learning experiences and academic achievement at upper secondary school in order to increase their enrolment and participation in STEM majors in higher education in Cambodia. First, optimizing learning experiences related to teaching science and mathematics should focus on providing a learning environment with a high level of interaction to push for cognitive activation. Put simply, increasing only teaching hours in the current science track would be misguided, and might not ignite inspiring learning experiences without considering more interactive teaching methods that involve inquiry-based and project-based teaching. Broadly speaking, changes to the intensive margins for improvement might include recruiting more qualified teachers, modifying student and teacher incentives, and improving teaching facilities and instructional materials that nurture an interactive learning atmosphere for science and mathematics. Noting these challenges, the lack of effects in expanding course access (documented in this study) suggests that for the Cambodian upper secondary school science track to be more effective in promoting students' STEM interest and success, the norms of upper secondary school instruction in science and mathematics classes (especially of the science track in traditional school) will need to be reconsidered and enhanced.

The process leading to entrance into STEM fields is complex, as it involves numerous influences of individual, psychological, contextual, and social factors. Together, they shape, develop, and sustain the students' interest, and eventually turning it into an actual choice. Also, since freedom of choice without guidance and information could mislead students to insufficiently prepare for some majors, more attention should be given to providing relevant information about higher education majors and STEM careers, especially among the underrepresented groups. Thus, explaining how track choice in general, and science track choice in particular, is associated with future majors and career prospects should be given special attention by the extant (or to be developed) *career counseling office* so that students could have enough information to make a *well-informed*, rather than an *uninformed* or *blind decision*. This will encourage students to have a better-informed, long-term future plan in general and in science in particular.

Relevant information about college majors and careers in STEM, targeted specifically toward underrepresented female subgroups should be considered. At the upper secondary school-level science track, females represents a higher proportion (53%). However, their science identity seemed shaded out when choosing STEM majors in higher education (approximately 17%). Thus, special priority should be given to enhance female competence and self-efficacy beliefs relating science and mathematics, so as to foster an early sense of identity as future scientists throughout the transition from secondary school to post-secondary education to work. Science teachers could also enhance parents' preconceptions and gender stereotypes relating to mathematics by raising their awareness of these processes. Again, the delivery of the aforementioned implications should be equitable for all vulnerable groups so that they could accumulate inspiring science learning experiences and pursue STEM majors in higher education.

8.5 Further studies

With its limitations, the current study has also thrown some implications for further study so as to elucidate the full landscape of students' decision to transition from upper secondary school to STEM in higher education in Cambodia. First, to gain a deeper insight into students' choices, a pragmatic investigation is crucial. Due to time constraints, the current study could only examine the issue based on students' aspirations of STEM majors in higher education. Thus, future study, in employing the mixed methods longitudinal designs (the present study's original design, which was redesigned due to the problem of data collection being interrupted by the Covid-19 pandemic), would provide an insightful understanding of the issue by scrutinizing students' final choice of major in higher education and utilizing the standardized science and mathematics scores. The analysis of the results should consider the type of HEIs (public, private, prestigious, etc.). Moreover, the study could follow up with students to identify who will stay in STEM for their final choice of major, and those who will switch to non-STEM. This future study could not only shed light on students' final choice, but also their retention in STEM in higher education.

Based on a longitudinal design, another study should investigate the performance of students who stay in STEM and those in non-STEM fields and their returns/investments to higher education across students from different types of upper secondary school (NGS and traditional schools). This would provide an evidence-based policy to enhance students' interest in STEM majors and to revisit some practices of traditional and new generation upper secondary schools. Actual classroom observation data on science and mathematics teachers teaching practice should be used. Additionally, understanding the full landscape of the changes in time-varying covariates at the end of grade 12^{th} would also be meaningful.

Last, experimental design study is crucial for examining the significant predictors of students' choice of STEM majors. For example, a quantitative study on the effects of implementing interactive teaching methods for science and mathematics lessons, or a study on promoting students' self-efficacy and outcome expectations in science and mathematics through experimental interventions in relation to students' interest in STEM, and finally their choice of STEM majors, would also be practical.

REFERENCES

Adelman, C. (1999). *Women and men of the engineering path: A model for analysis of undergraduate careers*. Washington D.C. National institute of science education.

Almeida, M.J., Leite, M.S., & Woolnough, B.E. (1998). Factors affecting students' choice of science and engineering in Portugal. *Research Report*, 1-10.

Anwer, M., Iqbal, H. M., & Harrison, C. (2012). Students' attitude towards science: A case of Pakistan. *Pakistan Journal of Social and Clinical Psychology*, *9*(2), 3-9.

Arnold, J. (2004). The congruence problem in John Holland's theory of vocational decisions. *Journal of Occupational and Organizational Psychology*, *77*(1), 95-113.

Arslan, Y. (2016). *Determinants of the choice of high school track in Turkey* [Unpublished master's thesis]. Institute of Social Science.

Asian Development Bank [ADB]. (2011). Improving instructional quality: Focus on faculty development [Study Report]. Higher Education in Dynamic Asia.

Asian Development Bank-International Labour Organization [ADB-ILO]. (2015). *Cambodia: Addressing the skills gap.* Mandaluyong City, Philippines: Asian Development Bank.

Awan, R. U. N., Sarwar, M., Naz, A., & Noreen, G. (2011). Attitudes toward science among school students of different nations: a review study. *Journal of College Teaching and Learning*, *8*(2), 43-50.

Ayalon, H., & Yogev, A. (1997). Students, schools, and enrollment in science and humanity courses in Israeli secondary education. *Educational Evaluation and Policy Analysis*, *19*(4), 339-353.

Ayres, D. M. (1999). The Khmer Rouge and education: beyond the discourse of destruction. *History of Education*, *28*(2), 205-218.

Ayres, D. M. (2000). Tradition, modernity, and the development of education in Cambodia. *Comparative Education Review*, *44*(4), 440-463.

Bagozii, R. B., & Burkrant, R. E. (1979). Attitude organization and the attitude behavior relationship. *Journal of Personality and Social Psychology*, *37*, 913-929.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*.

Bandura, A. (2010). Self-efficacy. *The Corsini Encyclopedia of Psychology*, 1-3.

Baran, M., & Maskan, A. (2011). The effect of project-based learning on pre-service physics teachers electrostatic achievements. *Cypriot Journal of Educational Sciences*, *5*(4), 243–257.

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education*, *30*(8), 1075-1093.

Becker, H. J. (1986). Instructional uses of school computers: Reports from the 1985 national survey, 1985 [Report No. ED 274.319]. Baltimore, MD: Center for Social Organisation of School.

Becker, K., Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations & Research*, *12*(5–6), 23–36.

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational behavior*, *23*(3), 329-345.

Bicer, A., Capraro, R. M., Capraro, M. M. (2018). Hispanic students' mathematics achievement in the context of their high school types as STEM and non-STEM schools. *International Journal of Mathematical Education in Science and Technology*, *49*(5), 705–720.

Bicer, A., Navruz B., Capraro, R. M., Capraro. M. M., Oner, T. A, Boedeker, P. (2015) STEM schools vs. non-STEM schools: Comparing students' mathematics growth rate on high-stakes test performance. *International Journal of New Trends in Education and Their Implications*, *6*(1), 138–150.

Bieri Buschor, C., Berweger, S., Keck Frei, A., & Kappler, C. (2014). Majoring in STEM—What accounts for women's career decision making? A mixed methods study. *The Journal of Educational Research*, *107*(3), 167-176.

Blaug, M. (1976). The empirical status of human capital theory: A slightly jaundiced survey. *Journal of Economic Literature, 14*(3), 827-855.

Bleeker, M.M., & Jacobs, J.E. (2004). Achievement in math and science: Do mother's beliefs matter 12 years later. *Journal of Educational Psychology, 96*(1), 97-109.

Bonous, H. (2000). Pathways to success: affirming opportunities for science, mathematics and engineering majors. *The Journal of Negro Education, 69*(1/2), 92-111.

Bottia, M. C., Stearns, E., Mickelson, R. A., Moller, S., & Valentino, L. (2015). Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM. *Economics of Education Review*, *45*, 14-27.

Brand, J. E., & Xie, Y. (2010). Who benefits most from college? Evidence from negative selection in heterogeneous economic returns to higher education. *American Sociological Review, 75*(2), 273-302.

Breakwell, G. M., & Beardsell, S. (2016). Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science*, *1*(2), 183-197.

Breiner et al. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3-11.

British Embassy. (2016). *STEM career of the future.* British Embassy. Phnom Penh, Kingdom of Cambodia.

Brown, P. (1995). Cultural capital and social exclusion: Some observations on recent trends in education, employment and the labour market. *Work, Employment and Society*, *9* (1), 29-51.

Brown, P. (1997) Cultural capital and social exclusion: Some observations on recent trends in education, employment and the labour market, in Halsey, A. H. et al. *Education: Culture, economy and society*, Oxford: Oxford University Press.

Brown, S. A. (1976). *Attitude goals in secondary school science*. University of Stirling. Department of Education.

Bryman, A. (2016). *Social research methods.* Oxford university press.

Bucher, R. (1979). Social structural constraints in career decision making occupational hurdles. In A. M. Mitchell, G. B. Jones, & J. D. Krumboltz (Eds.), *Social learning and career decision making* (pp. 116-133). Cranston, RI: Carroll Press.

Cambodia Development Resource Institute [CDRI]. (2015). *Cambodia education 2015: Employment and empowerment?* Phnom Penh, Kingdom of Cambodia.

Cambodia Development Resource Institute [CDRI]. (2018). *Cambodia development research forum (DRF) symposium 2018: Post-secondary education development through multi-stakeholder engagement.* Phnom Penh, Kingdom of Cambodia.

Cambodian Federation of Employers and Business Association [CAMFEBA]. (2008). *Youth and employment: Bridging the gap. A study about youth and employer perspective on education, skills, opportunities and the future*. Youth Employment and social dialogue project YEP Project.

Center for Research and Development Strategy [CRDS]. (2015). *Current status on science and technology in ASEAN countries*. Oversea Research Report. Japan Science and Technology Agency

Chen, X., (2013). *STEM Attrition: College Students' Paths into and out of STEM Fields.* Statistical Analysis Report. NCES 2014-001. National Center for Education Statistics.

Chen, X., & Soldner, M. (2014). *STEM attrition: College students' path into and out of STEM field.* National Center of Education Statistics.

Chen, X., & Weko, T., (2009). *States in brief: Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education.* National Center for Education Statistics. U.S. Department of Education.

Chey, C. O., & Khieu, V. (2017). Cognitive domain, level of difficulty and topic distribution of the science stream in the national exit examination in Cambodia. *Cambodia Education Review, 1*(1), 33-48.

Chhinh, S., Edwards Jr. B., Williams, H.J., & Yu, K. (2015) In Hawkins, N.J. and Jacob, W.J. (Eds). *The political economy of schooling in Cambodia. Issues of quality and equity. introduction.* Palgrave Machillan, 3-11.

Chonkaew, P., Sukhummek, B., Faikhamta, C. (2016). Development of analytical thinking ability and attitudes towards science learning of grade-11 students through science technology engineering and mathematics (STEM education) in the study of stoichiometry. *Chemistry Education Research and Practice*, *17*(4), 842–861.

Clayton, T., & Yuok, N. (1997). Cambodia. In Gerard, P. & Grace, M. (Ed), *Asian higher education* (pp. 21-36). Westport, Conn.: Greenwood Press.

Cohen, J. (1988). *Statistical power analysis for the behavioral science* (2nd Eds). Hillsdale, NJ: Lawrence Earlbaum Association.

Cohen, L. M. L., & Morrison, K. (2007). *Research methods in education 6th edition.* London: Rouledge.

Conrad, S., Canetto, S. S., MacPhee, D., & Farro, S. (2009). What attracts high-achieving socioeconomically disadvantaged students to the physical sciences and engineering? *College Student Journal*, *43*(4), 1359.

Crawley, F. E., & Black, C. B. (1992). Causal modeling of secondary science students' intentions to enroll in physics. *Journal of Research in Science Teaching*, *29*(6), 585-599.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Crisp, G., Nora, A., & Taggart, A., (2009). Student characteristics, pre-college, college, and environmental factors as predictors of majoring in and earning a STEM degree: An analysis of students attending a Hispanic serving institution. *American Educational Research Journal, 46*(4), 924-942.

Dainton, F. S. (1968). *The Dainton Report*: An inquiry into the flow of candidates into science and technology.

Darolia, R., Koedel, C., Main, J. B., Ndashimye, J. F., & Yan, J. (2018). High School Course Access and Postsecondary STEM Enrollment and Attainment. *Educational Evaluation and Policy Analysis*, *42*(1), 22-45.

DeBoer, G.F. (1987). Predicting continue participation in college chemistry for men and women. *Journal of Research in Science Teaching, 24*(6), 527-538.

DesJardins, S. L., Dundar, H., & Hendel, D. D. (1999). Modeling the college application decision process in a land-grant university. *Economics of Education Review, 18*, 117-132.

Dick, T.P., & Rallis, S.F. (1991). Factors influences on high school students' career choices. *Journal for Research in Mathematics Education*, *22*(4), 281-292.

Dom, V., & Yi, G. (2018). Gender and Subject Choice: An Empirical Study on Undergraduate Students' Majors in Phnom Penh. *Online Submission*, *7*(1), 40-47.

Durdyev, S., & Ihtiyar, A. (2019). Structural equation model of factors influencing students to major in architecture, engineering, and construction. *Journal of Professional Issues in Engineering Education and Practice*, *145*(2), 1-8.

Dustmann, C. (2004). Parental background, secondary school track choice, and wages. *Oxford Economic Papers*, *56*(2), 209-230.

Dustmann, C., Puhani, P. A., & Schönberg, U. (2017). The long-term effects of early track choice. *The Economic Journal*, *127*(603), 1348-1380.

Eam, P., Keo, B., Leng, P., Song, S., & Khieng, S. (2019). Correlates of STEM major choice: a quantitative look at Cambodian university freshmen. *Research in Science & Technological Education*, ahead-of-printing, 1-19.

Eccles, E. (1994). College majors choice and change in the gender wage gap. *Contemporary Economic Policy, 12,* 47-66.

Ekmekci, A., Sahin, A., & Waxman, H. (2019). Factors Affecting Students' STEM Choice and Persistence: A Synthesis of Research and Findings from the Second Year of a Longitudinal High School STEM Tracking Study. In *STEM Education 2.0* (pp. 279-304). Brill Sense.

Eng, S., & Szmodis, W. (2016). Stem Learning Achievement among Cambodian Middle School Students: An Examination of Gender and Psychosocial Factors. In *Annual Review of Comparative and International Education 2015* (pp. 279-305). Emerald Group Publishing Limited.

Engle, J., & Tinto, V. (2008). *Beyond access: College success for low income, first generation students*. Washington, DC: Pell Institute.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, *3*(1), 3.

Erdogan, N., & Stuessy, C. L. (2015). Modeling successful STEM high schools in the United States: An ecology framework. *International Journal of Education in Mathematics, Science and Technology, 3*(1), 77-92.

Evans, C. A., Chen, R., & Hudes, R. P. (2020). Understanding Determinants for STEM Major Choice Among Students Beginning Community College. *Community College Review*, *48*(3), 227-251.

Field, A. (2009). *Discopering statistics using SPSS (3rd Ed)*. Sage publication.

Fleming, L., Engerman, K., & Griffin, A. (2005). Persistence in engineering education: Experiences of first year students at a historically black university. In *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education* (pp. 1-7).

Forsthuber, B., Motiejunaite, A., & de Almeida Coutinho, A. S. (2011). *Science education in Europe: national policies, practices and research*. Education, Audiovisual and Culture Executive Agency, European Commission.

Fouad, N. A., & Smith, P. L. (1996). A test of a social cognitive model for middle school students: Math and science. *Journal of Counseling Psychology*, *43*(3), 338-346.

Fouad, N. A., Smith, P. L., & Enochs, L. (1997). Reliability and validity evidence for the middle school self-efficacy scale. *Measurement and Evaluation in Counseling and Development*, *30*(1), 17-31.

Francis, L. J., & Greer, J. E. (1999). Measuring attitude towards science among secondary school students: The affective domain. *Research in Science & Technological Education*, *17*(2), 219-226.

Fraser, B. J. (1981). *TOSRA: Test of science-related attitudes: Handbook*. Australian Council for Educational Research.

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *34*(4), 343-357.

Freeman, B.; Marginson, S. & Tytler, R. (Eds.). (2015). *The age of STEM: Educational policy and practice across the world in science, technology, engineering and mathematics.* Routledge.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: current use, calculations, and interpretation. *Journal of experimental psychology: General*, *141*(1), 2-18.

Furnham, A. (2001). Vocational preference and P-O fit: reflections on Holland's theory of vocational choice, *Applied Psychology: An International Review, 50*(1), 5-29.

Gamoran, A. (1992). The variable effects of high school tracking. *American Sociological Review*, 812-828.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education, 2*(1975), 1-44.

Gaskell, P.J., Mclaren, A., Oberg, A., & Eyre, L. (1993). The 1990 British Columbia Mathematics Assessment: Gender issue in choice of mathematics and science. *Gender And Education-Abingdon*, *6*, 220-220.

George, C.E. (2012). Generation me: Influence of students' choice of major. *Project STEP-UP*. University of Illinois at Urbana-Champaign.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology*, *9*(3), 213-225.

George, R. (2006). A cross-domain analysis of change in students’ attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571-589.

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching*, *25*(8), 689-703.

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*(5), 693-705.

Goyette, K. A., & Mullen, A. L. (2006). Who study the arts and sciences? Social background and the choice and consequences of undergraduate field of study. *The Journal of Higher Education, 77*(3), 497-538.

Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A. B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. *Science*, *341*(6153), 1455-1456.

Grandy, J. (1992). Graduate enrollment decisions of undergraduate science and engineering majors: A survey of GRE test takers [GRE Board Report No. 85-01P]. Princeton.

Green, M. (2007). Science and engineering degrees: 1966-2004. *Virginia: National Science Foundation*, pp. 1-72. Science Resources Statistics.

Guba, E. G. (1990). The paradigm dialog. In *Alternative paradigms conference, Mar, 1989, Indiana U, school of education, San Francisco, CA, US*. Sage Publications, Inc.

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles*, *66*(3-4), 153-166.

Hacieminoglu, E. (2016). Elementary School Students' Attitude toward Science and Related Variables. *International Journal of Environmental and Science Education*, *11*(2), 35-52.

Hackett, C. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: a path analysis. *Journal of Counseling Psychology*, *31*(1), 47-56.

Hackett, G., & Betz, N. E. (1981). A self-efficacy approach to the career development of women. *Journal of Vocational Behavior*, *18*(3), 326-339.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher, and learning environment variables to attitudes toward science. *Science Education*, *66*(5), 671-687.

Hammrich, P. (1998). Promoting females’ success in science. *Journal of Supervision and Curriculum Development*, *1*(4), 20-24.

Han, S., & Buchmann, C. (2016). Aligning science achievement and STEM expectations for college success: A Comparative study of curricular standardization. *RSF: The Russell Sage Foundation Journal of the Social Sciences*, *2*(1), 192-211.

Handley, H. M., & Morse, L. W. (1984). Two-year study relating adolescents' self-concept and gender role perceptions to achievement and attitudes toward science. *Journal of Research in Science Teaching*, *21*(6), 599-607.

Hanushek, E. A., & Wößmann, L. (2006). Does educational tracking affect performance and inequality? Differences-in-differences evidence across countries. *The Economic Journal*, *116*(510), C63-C76.

Harwell, E. (2012). An analysis of parent occupation and student choice in STEM majors. *Project STEP-UP*. University of Illinois at Urbana-Champaign.

Heaverlo, C. (2011). STEM development: A study of 6th-12th grade girls' interest and confidence in mathematics and science (Unpublished doctoral dissertation), Iowa State University, United States of America.

Hechter, M., & Kanazawa, S. (1997). Sociological rational choice theory. *Annual Review of Sociology*, *23*(1), 191-214.

Hill, N. E., & Tyson, D. F. (2009). Parental involvement in middle school: a meta-analytic assessment of the strategies that promote achievement. *Developmental Psychology*, *45*(3), 740.

Hodson, D., & Freeman, P. (1983). The effect of primary science on interest in science: some research problems. *Research in Science & Technological Education*, *1*(1), 109-118.

Hogan, R., & Blake, R. (1999). John Holland's vocational typology and personality theory. *Journal of Vocational Behavior*, *55*(1), 41-56.

Holland, J. L. (1959). A theory of vocational choice. *Journal of Counseling Psychology*, *6*(1), 35-45.

Holland, J. L. (1966). *The psychology of vocational choice: A theory of personality types and model environments*. Waltham, MA: Blaisdell.

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2014). To choose or not to choose science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education*, *36*(2), 186-215.

Hossler, D., Braxton, J., & Coopersmith, G. (1989). Understanding student college choice. *Higher education: Handbook of theory and research*, *5*, 231-288.

Hu, N.B. (1996). Effects of college students' perception of labor market variables and conditions on their choice of academic majors. *Eric 1996 Annual Forum Paper*.

Huang, G., Taddese, N., Walter, E. (2000). Entry and persistence of women and minorities in college science and engineering education. [Research and Development Report ED444872], ERIC.

Ishikawa, M., Fuji. S., & Moehle, A. (2013). *STEM country comparison: Japan.* Retrieved May 01, 2018, from https://acola.org.au/wp/stem-consultants-reports/.

Ito, T. A., & McPherson, E. (2018). Factors influencing high school students' interest in pSTEM. *Frontiers in Psychology*, *9*, 1-13.

Ivankova, N. V., & Stick, S. L. (2007). Students' persistence in a distributed doctoral program in educational leadership in higher education: A mixed methods study. *Research in Higher Education*, *48*(1), 93-135.

Japan International Cooperation Agency [JICA]. (2016). Data collection survey on human resource development for industrialization in the education sector in the Kingdom of Cambodia. Final Report [HM-JR-16-042], JICA, Kingdom of Cambodia.

Jone, G., Howe, A., & Rua, M. (2000). Gender differences in students' experiences, interests, and attitude towards science and scientists. *Science Education*, *84*(1), 180-192.

Judson, E. (2014). Effects of transferring to STEM-focused charter and magnet schools on student achievement. *The Journal of Educational Research*, *107*(4), 255–266.

Kaing. S. (2016). *How can STEM education help stimulate economic growth in Cambodia.* (Unpublished Master's Thesis). Vrije Universiteit, Brussel.

Kao, S. (2019a). Cambodian Upper Secondary School Students' Attitudes towards Science: Trends and Patterns. *Journal of International Development and Cooperation,* 26(1), 15-27.

Kao, S. (2019b). Family socioeconomic status and students' choice of STEM majors. *International Journal of Comparative Education and Development*, *22*(1), 49-65.

Kao, S., & Shimizu, K. (2019). Factors affecting students' choice of science and engineering majors in higher education of Cambodia. *International Journal of Curriculum Development and Practice, 21*(1), 69-82.

Kelly, A. (1988). Option choice for girls and boys. *Research in Science and Technology Education, 6*(1), 5-23.

Kerr, S. P., Pekkarinen, T. & Uusitalo, R. (2013). School tracking and development of cognitive skills. *Journal of Labor Economics, 31*(3), 577–602.

Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching*, *40*(9), 898–921.

Kienzl, G. S., & Trent, W. T. (2009). *Underrepresented undergraduates in STEM: From matriculation to degree completion at large, research-intensive public universities.*

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM career interest survey (STEM-CIS). *Research in Science Education*, *44*(3), 461-481.

Kind, P. M., Jones, K., & Barmby, P. (2007). Developing attitude towards science measure. *International Journal of Science Education, 29*(7), 871-893.

Kinyota, M. (2013). Students' perceptions of factors influencing choice of science streams in Tanzania secondary schools (Master's thesis). Available from Master's Capstone Projects (166).

Koballa Jr, T. R. (1988). The determinants of female junior high school students' intentions to enroll in elective physical science courses in high school: Testing the applicability of the theory of reasoned action. *Journal of Research in Science Teaching*, *25*(6), 479-492.

Krumboltz, J.D. (1979). A social learning theory of career decision making. In A. M. Mitchell, G. B. Jones, & J.D. Krumboltz (Eds). *Social learning and career decision making* (pp.19-49). Cranston, RI: Carroll Press.

Kwak, Y. (1993). A study of academic high school female students' choice of major fields of study. *The Study of Sociology of Education, 3*(1), 79-106.

Lapan, R.T., Boggs, K.R. & Morrill, W.H. (1989). Self-efficacy as a mediator of investigative and realistic general occupational themes on the strong-Campbell interest inventory. *Journal of Counseling Psychology, 31*, 356-362.

Lavy, V., & Sand, E. (2015). On the origins of gender human capital gaps: Short and long term consequences of teachers' stereotypical biases [Report No. w20909]. National Bureau of Economic Research.

Lee, J. (2009). Universals and specifics of math self-concept, math self-efficacy, and math anxiety across 41 PISA 2003 participating countries. *Learning and Individual Differences*, *19*(3), 355-365.

Lee, O., & Luykx, A. (2006). *Science education and student diversity: Synthesis and research agenda*. Cambridge University Press.

Lee, S. W., Min, S., & Mamerow, G. P. (2015). Pygmalion in the classroom and the home: Expectation's role in the pipeline to STEMM. *Teachers College Record*, *117*(9), 1-36.

Lee, V. E. (1987). Identifying Potential Scientists and Engineers: An Analysis of the High School-College Transition. Report 2: Multivariate Analysis of the High School Class of 1982 [Technical Report ED308063]. ERIC.

Leech, N., Barrett, K., & Morgan, G. A. (2005). *SPSS for intermediate statistics: Use and interpretation (2nd ed)*. Lawrence Erlbaum Associates, Inc., Publishers

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*, 79-122.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. *Career Choice and Development*, *4*, 255-311.

Lent, R. W., Lopez Jr, A. M., Lopez, F. G., & Sheu, H. B. (2008). Social cognitive career theory and the prediction of interests and choice goals in the computing disciplines. *Journal of Vocational Behavior*, *73*(1), 52-62.

Lent, R. W., Sheu, H. B., Miller, M. J., Cusick, M. E., Penn, L. T., & Truong, N. N. (2018). Predictors of science, technology, engineering, and mathematics choice options: A meta-analytic path analysis of the social–cognitive choice model by gender and race/ethnicity. *Journal of Counseling Psychology*, *65*(1), 17-35.

Lent, R.W., Lopez, F.G., & Bieschke, K.J. (1991). Mathematics self-efficacy: Sources and relation to science based career choice. *Journal of Counseling Psychology*, *38*(4), 424-430.

Lent, R.W., Lopez, F.G., & Bieschke, K.J. (1993). Predicting mathematics-related choice and success behaviors: Test of an expanded social cognitive model. *Journal of Vocational Behavior*, *42*(2), 223-236.

Lent, R.W., Sheu, H.B., Singley, D., Schmidt, J.A., Schmidt, L.C., & Gloster, C.S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73*(2), 328-335.

Leong, F. T. L., Austin, J. T., Sekaran, U., & Komarraju, M. (1998). An evaluation of the cross-cultural validity of Holland's theory: Career choices by workers in India. *Journal of Vocational Behavior, 52*(3), 441-455.

Leppel, K., Williams, M. L., & Waldauer, C. (2001). The impact of parental occupation and socioeconomic status on choice of college major. *Journal of Family and Economic Issues*, *22*(4), 373-394.

Leslie, L.L., McClure, G.T., & Oaxaca, C.L. (1998). Women and minorities in science and engineering: A life sequence analysis. *The Journal of Higher Education*, *69*(3), 239-276.

LeTendre, G. K., Hofer, B. K., & Shimizu, H. (2003). What is tracking? Cultural expectations in the United States, Germany, and Japan. *American Educational Research Journal*, *40*(1), 43-89.

Li, X., & Kuan, P. Y. (2018). The effect of single-sex schooling on high school girls' curriculum tracking selection in Taiwan. *International Sociological Association*, 302-303.

Lichtenberger, E., & George-Jackson, C. (2013). Predicting High School Students' Interest in Majoring in a STEM Field: Insight into High School Students' Postsecondary Plans. *Journal of Career and Technical Education*, *28*(1), 19-38.

Lincoln, Y. S., Lynham, S. A., & Guba, E. G. (2011). Paradigmatic controversies, contradictions, and emerging confluences, revisited. *The Sage Handbook of Qualitative Research*, *4*, 97-128.

Lindner, J.R. et al. (2004) Students' belief about science and sources of influence affecting science career choice. *NACTA Journal*, 1-7.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education*, *6*(4), 297-306.

Lowinger, R., & Song, H. A. (2017). Factors Associated with Asian American Students' Choice of STEM Major. *Journal of Student Affairs Research and Practice*, *54*(4), 415-428.

Lucas, S. R. (1999). *Tracking inequality: Stratification and mobility in American high schools. Sociology of education series*. Teachers College Press, 1234 Amsterdam Avenue, New York, NY 10027.

Ma, Y. (2009). Family socioeconomic status, parental involvement, and college major choices: gender, race/ethnic, and nativity patters. *Social Perspectives, 55,* 211-234.

Mak, N. (2012). *Cambodia higher education: Challenges, opportunities and future directions.* A paper presented at policy roundtable on higher education and vocational training in Cambodia, 30 August 2012. Phnom Penh, Kingdom of Cambodia.

Malecki, C. K., & Demaray, M. K. (2002). Measuring perceived social support: Development of the child and adolescent social support scale (CASSS). *Psychology in the Schools*, *39*(1), 1-18.

Malecki, C. K., Demaray, M. K., & Elliott, S. N. (2003). A working manual on the development of the child and adolescent social support scale (2000) (Unpublished manuscript). Northern Illinois University.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877-907.

Maltlese, A.V.; Lung, F. D.; Potvin, G., & Hochbein, C.D. (2013). STEM education in the United States. Retrieved May 01, 2018, from https://acola.org.au/wp/stem-consultants- reports/.

Marginson, S.; Tytler, R.; Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons: International comparisons of science, technology, engineering, and mathematics (STEM) education* [Final report]. Australian Council of Learned Academies, Melbourne, Vic.

Matsui, T., Matsui, K., & Ohnishi, R. (1990). Mechanism underlying math self-efficacy learning of college students. *Journal of Vocational Behavior*, *37*, 225-238.

Mau, W. C. J., & Li, J. (2018). Factors influencing STEM career aspirations of underrepresented high school students. *The Career Development Quarterly*, *66*(3), 246-258.

McGuire, W. J. (1985). Attitude and attitude change. In G. Lindzey, & E. Aronson (Eds.) *Handbook of Social Psychology* (pp. 233-345). New York, NY: Random House.

McMahon, J. M., Pouget, E. R., & Tortu, S. (2006). A guide for multilevel modeling of dyadic data with binary outcomes using SAS PROC NLMIXED. *Computational statistics & data analysis*, *50*(12), 3663-3680.

Means, B., Wang, H., Wei, X., Iwatani, E., & Peters, V. (2018). Broadening participation in STEM college majors: Effects of attending a STEM-focused high school. *AERA Open*, *4*(4), 1-17.

Means, B., Wang, H., Young, V., Peters, V. L., Lynch, S. J. (2016). STEM-focused high schools as a strategy for enhancing readiness for postsecondary STEM programs. *Journal of Research in Science Teaching*, *53*(5), 709–736.

Meece, J.L., Parsons, J.E., Kaczala, C.M., Goff, S.B., & Fatterman, R. (1982). Sex difference in math achievement: toward a model of academic choice. *Psychological Bulletin, 91*, 324-348.

Menis, J. (1989). Attitude towards school, chemistry students and science among upper secondary chemistry students in the United States, *Research in Science and Technological Education, 7*(2), 183-190.

Mertens, D. M. (2014). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage publications.

Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E., Anderman, L., Freeman, K. E., & Urdan, T. (2000). Manual for the patterns of adaptive learning scales. *Ann Arbor: University of Michigan*.

Miller, J. D., & Kimmel, L. G. (2012). Pathways to a STEMM profession. *Peabody Journal of Education*, *87*(1), 26-45.

Ministry of Education, Youth and Sport [MoEYS]. (2002). *Regulation on admission into higher education system.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2004). *Policy for curriculum development 2005-2009*. Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2006). *Core curriculum for basic general education*. Department of pedagogical research, Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS], (2009). *Announcement 09 dated on 10 July, 2009 on subject required in entrance examination into foundation year program for first year of Bachelor's degree.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2010). *Announcement No. 23 on the implementation of new curriculum at upper secondary education*. Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2010). *Guidelines on the implementation of curriculum at upper secondary education: grades 11 and 12*. Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2014a). *Higher education vision 2020–2030.* Department of Higher Education, Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2014b) *Results of upper secondary school completion examination 1980–2013*. Phnom Penh: Ministry of Education, Youth and Sport, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2014c). *Announcement No. 97 dated 31 December 2014 on the temporary suspension of license issuance of accounting, banking, and finance majors in higher education.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2015). *Tracer study: Follow-up report.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2016a). *Policy on science, technology, engineering and mathematics (STEM) education.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2016b). *Statistic of higher education enrollment.* Department of Higher Education, Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2016c). *Policy on new generation school.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2017). *Statistic of enrolment in science and social track at general education*. Department of general education, Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018a). *Achievement in education sector from 1998 to 2018.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018b). *Announcement No.11 on the implementation of Baccalaureate examination for academic year 2017–18.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018c). *Resource school document* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018d). *The STEM brochure.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018e). *Operational policy guidelines for new generation schools.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018f). *Announcement on government scholarship selection for the academic year 2019-2020.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2018g). *Education in Cambodia: Findings from Cambodia's experience in PISA for Development*. Phnom Penh: Author.

Ministry of Education, Youth and Sport [MoEYS]. (2018h). *Education congress document on achievement of MoEYS in 2016-2017 and direction for 2017-2018*. (Report), Institute of Technology of Cambodia, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019a). *Education strategic plan 2019–2023.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019b). *Education congress report on the achievement for the academic Year 2018-2019 and direction for 2019-2020.* (Report), MoEYS, Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019c). *Education statistic compiled by Department of General Education.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019d). *Education statistic compiled by Department of Higher Education.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019e). *Announcement number 10 on the implementation of Prakas 154 dated on 29 January 2019 on planning and implementing of upper secondary school national examination for the academic year 2018-2019.* Phnom Pend, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2019f). *Statistics on students passing the Baccalaureate examination in 2019.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2020a). *Actional operation plan 2020.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2020b). *Announcement number 44 on the implementation of Prakas 154 dated on 29 January 2019 on planning and implementing of lower secondary school national examination for the academic year 2019-2020*. Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2020c). *Guidebook on higher education institutions and academic majors selection.* Phnom Penh, Kingdom of Cambodia.

Ministry of Education, Youth and Sport [MoEYS]. (2020d). *Education congress report on the achievement in 2018-2019 and direction for 2019-2020.* Phnom Penh, Kingdom of Cambodia.

Mitchell, P. T. (2016). Undergraduate motivations for choosing a science, technology, engineering, or mathematics (STEM) major. *University of Tennessee Honors Thesis Projects.*

Moakler Jr, M. W., & Kim, M. M. (2014). College major choice in STEM: Revisiting confidence and demographic factors. *The Career Development Quarterly*, *62*(2), 128-142.

Montmarquette, C., Cannings, K., & Mahseredjian, S. (2002). How do young people choose college majors?. *Economics of Education Review*, *21*(6), 543-556.

Morrison, J., Roth, McDuffie, A., French, B. (2015). Identifying key components of teaching and learning in a STEM school. *School Science and Mathematics*, *115*(5), 244–255.

Mullen, A. L. (2011). *Degrees of inequality: Culture, class, and gender in American higher education*. JHU Press.

Myeong, J, O., & Crawley, F., E. (1991). Predicting and understanding Korean high school students’ science track choice: Testing the theory of reasoned action by structural equation modeling [Technical Report No. 143]. ERIC.

Myeong, J. O., & Crawley, F. E. (1993). Predicting and understanding Korean high school students' science track choice: Testing the theory of reasoned action by structural equation modeling. *Journal of Research in Science Teaching*, *30*(4), 381-400.

National Center for Education Statistics [NCES]. (2020). Classification of institutional program (CIP). Retrieved December 10, 2019, from https://nces.ed.gov/ipeds/cipcode/searchresults.aspx?y=56&cf=90495.

National Employment Agency [NEA]. (2018). *Cambodia job outlook 2018*. Phnom Penh, Kingdom of Cambodia.

National Research Council [NRC]. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. National Academies Press.

Nauta, M. M., & Epperson, D. L. (2003). A longitudinal examination of the social-cognitive model applied to high school girls' choices of nontraditional college majors and aspirations. *Journal of Counseling Psychology*, *50*(4), 448-457.

Navarro, R. L., Flores, L. Y., & Worthington, R. L. (2007). Mexican American middle school students' goal intentions in mathematics and science: A test of social cognitive career theory. *Journal of Counseling Psychology*, *54*(3), 320-335.

Nicholls, G.M., Wolfe, H., Besterfield-Sacre, M., Shuman, L.J., & Larpkiattaworn, S. (2007). A method for identifying variables for predicting STEM enrollment. *Journal of Engineering Education*, *696*(1), 33-44.

Niu, L. (2013). Choosing an undergraduate stem major: Family socioeconomic status, individual, and institutional factors. (Unpublished doctor dissertation). University of Florida, USA.
Niu, L. (2017). Family socioeconomic status and choice of stem major in college: An analysis of a national sample. *College Student Journal*, *51*(2), 298-312.
Nix, S., Perez-Felkner, L., & Thomas, K. (2015). Perceived mathematical ability under challenge: a longitudinal perspective on sex segregation among STEM degree fields. *Frontiers in Psychology*, *2015*(6), 1-19.
Nosek, B.A., & Smyth, F.L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. *American Educational Research Journal, 48*(5), 1125-1156.
Nugent, G., Barker, B., & Welch, G., Grandgenett, N., Wu, C., & Nelson, C. (2015). A model of STEM learning and career orientation based on social cognitive theory. *International Journal of Science Education*, 37(7), 1067-1088.
Oakes, J. (1986). Keeping track, part 1: The policy and practice of curriculum inequality. *Phi Delta Kappan*, *68*(1), 12-17.
Oakes, J. (1990). Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science [Technical Report]. ERIC.
Olaniyan, D. A., & Okemakinde, T. (2008). Human capital theory: Implications for educational development. *Pakistan Journal of Social Sciences*, *5*(5), 479-483.
Oliveira, E. & Roberts, K. (2013). Literature review: STEM education in France. Retrieved May 21, 2018, from https://acola.org.au/wp/PDF/SAF02 Consultants/ Consultant%20 Report%20-%20France.pdf.
Organization for Economic Co-operation and Development [OCDE]. (2004). *Learning for Tomorrow's World: First Results from PISA 2003.* OECD Publishing.
Organization for Economic Cooperation and Development [OECD]. (2016), "Students' attitudes towards science and expectations of science–related careers", in *PISA 2015 Results (Volume I): Excellence and Equity in Education*, OECD Publishing, Paris, https://doi.org/10.1787/9789264266490-7-en.
Organization for Economic Cooperation and Development [OECD]. (2017). *Database on Education at a glance.* Retrieved Mary 30, 2018, from https://stats.oecd.org/ Index. aspx? datasetcode=EAG_ENRL_MOBILES_FIELDS.
Ormerod, M. B., & Duckworth, D. (1975). *Pupils' attitudes to science: A review of research.* Windsor, Berks: NFER Pub.
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049-1079.
Owens, E. W., Shelton, A. J., Bloom, C. M., & Cavil, J. K. (2012). The significance of HBCUs to the production of STEM graduates: Answering the call. *Educational Foundations*, *26*, 33-47.
Paik, S., & Shim, W. J. (2013). Tracking and college major choices in academic high schools in South Korea. *The Asia-Pacific Education Researcher*, *22*(4), 721-730.
Palmer, R. T., Maramba, D. C., & Dancy, T. E. (2011). A qualitative investigation of factors promoting the retention and persistence of students of color in STEM. *The Journal of Negro Education*, *80*(4), 491-504.

Papanastasiou, C., & Papanastasiou, E. C. (2004). Major influences on attitudes toward science. *Educational Research and Evaluation*, *10*(3), 239-257.

Pen, S. (2011). Factor affecting high school students' aspiration on choice of major at post-secondary education (Unpublished Master's Thesis). Nagoya University, Japan.

Peou, C. (2017). On Cambodian higher education and skills mismatch: Young people choosing university majors in a context of risk and uncertainty. *Journal of Education and Work*, *30*(1), 26-38.

Pike, G. R. (2006). Students' personality types, intended majors, and college expectations: Further evidence concerning psychological and sociological interpretations of Holland's theory. *Research in Higher Education*, *47*(7), 801-822.

Pit, C., & Ford, D. (2004). *Cambodian higher education: Mixed visions. Asian universities: Historical perspectives and contemporary challenges*, Altbach P & Umakoshi T (eds), The Johns Hopkins University Press: Baltimore, MA. pp. 333-362.

Porter, S.R., & Umbach, P.D. (2006). College major choice: An analysis of Person-Environment Fit. *Research in Higher Education, 47*(4), 429-449.

Potvin, P., Hasni, A., Sy, O., & Riopel, M. (2018). Two crucial years of science and technology Schooling: A longitudinal study of the major influences on and interactions between self-concept, interest, and the intention to pursue S&T. *Research in Science Education*, 1-23, https://doi.org/10.1007/s11165-018-9751-6.

Rakow, S. J., & Bermudez, A. B. (1993). Science is" ciencia": Meeting the needs of Hispanic American students. *Science Education*, *77*(6), 669-683.

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892-900.

Raudenbush, S. W., Bryk, A. S., Cheong, Y. F., Congdon, R., & Du Toit, M. (2019). *HLM 8: Hierarchical Linear and Nonlinear Modeling.* Scientific Software International. Inc., Lincolnwood, IL.

Raykov, T. (2011). Intraclass correlation coefficients in hierarchical designs: Evaluation using latent variable modeling. *Structural Equation Modeling*, *18*(1), 73-90.

Riegle-Crumb, C., & King, B. (2010). Questioning a white male advantage in STEM: Examining disparities in college major by gender and race/ethnicity. *Educational Researcher*, *39*(9), 656-664.

Riegle-Crumb, C., King, B., Grodsky, E., & Muller, C. (2012). The more things change, the more they stay the same? Prior achievement fails to explain gender inequality in entry into STEM college majors over time. *American Educational Research Journal*, *49*(6), 1048-1073.

Royal Government of Cambodia [RGC]. (2007). *Education law.* Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2013). *Cambodia's national science and technology master plan for growth and quality of life.* Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2015). *Cambodia industrial development policy 2015–2025. "Market orientation and enabling environment for industrial development."* Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2017). *National technical vocational education and training policy 2017-2025.* Ministry of Labour and Vocational Training, Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2018*). "Rectangular strategy" for growth, employment, equity, and efficiency phase IV.* Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2019a). *National strategic development plan updated 2014–2018: For growth, employment, equity and efficiency to reach the Cambodian millennium development goal.* Phnom Penh, Kingdom of Cambodia.

Royal Government of Cambodia [RGC]. (2019b). *National policy on science, technology, and innovation 2020-2030.* Phnom Penh, Kingdom of Cambodia.

Ruse, P., & Xu, Y. (2018). Original Paper Secondary School Variables in Predicting Technology, Engineering, Mathematics (TEM) Major Choice. *Children and Teenagers, 1*(1), 49-62.

Sahin, A. (2013). STEM clubs and science fair competitions: Effects on post-secondary matriculation. *Journal of STEM Education*, *14*(1), 5–11.

Sahin, A., Ekmekci, A., & Waxman, H. C. (2017). The relationships among high school STEM learning experiences, expectations, and mathematics and science efficacy and the likelihood of majoring in STEM in college. *International Journal of Science Education, 39*(11), 1549-1572.

Sahin, A., Gulacar, O., & Stuessy, C. (2015). High school students' perceptions of the effects of international science Olympiad on their STEM career aspirations and twenty-first century skill development. *Research in Science Education*, *45*(6), 785-805.

Sam, K. (2020). *New generation school management.* Power point presentation during MoEYS 2020 education congress, Phnom Penh, Kingdom of Cambodia.

Sam, R., Zain, A. N. M., & Jamil, H. (2012). Cambodia's higher education development in historical perspectives (1863-2012). *International Journal of Learning and Development*, *2*(2), 224-241.

Sam, V. (2018). Unemployment duration and educational mismatches: An empirical investigation among graduates in Cambodia. *Economics Bulletin, 38*(3), 1554-1565.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, 20-26.

Sar M (2014) *Science teachers' perception on teacher center and inquiry-based approach at upper secondary level in Cambodia* [unpublished master thesis]. Hiroshima University, Japan.

Sawilowsky, S (2009). New effect size rules of thumb. *Journal of Modern Applied Statistical Methods. 8*(2): 467-474.

Sax, L. J., Kanny, M. A., Riggers-Piehl, T. A., Whang, H., & Paulson, L. N. (2015). "But I'm not good at math": The changing salience of mathematical self-concept in shaping women's and men's STEM aspirations. *Research in Higher Education*, *56*(8), 813-842.

Sax, L.J. (1996). The impact of college on post-college commitment to science careers: Gender differences in a nine-year follow-up of college freshmen. (Research Report). ERIC, Higher Education Research Institute.

Scantlebury, K., Boone, W., Kahle, J. B., & Fraser, B. J. (2001). Design, validation, and use of an evaluation instrument for monitoring systemic reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(6), 646-662.

Scott, A.B., Mallinckrodt, B. (2005). Parental emotional support, science self-efficacy, and choice of science majors in undergraduate women. *The Career Development Quarterly, 53*, 263-273.

Scott, C. E. (2012). An investigation of science, technology, engineering and mathematics (STEM) focused high schools in the US. *Journal of STEM Education: Innovations and Research*, *13*(5), 30–39.

Scott, J. (2000). Rational choice theory. *Understanding contemporary society: Theories of the present*, *129*.

Selema, T. (2010). Who is joining physics and why? Factors affecting the choice of physics among Ethiopian university students. *International Journal of Environmental & Science Education, 5*(3), 319-340.

Sen, V., & Ros, S. (2013). *Anatomy of higher education governance in Cambodia*. Phnom Penh, Kingdom of Cambodia.

Serin, O., & Mohammadzadeh, B. (2008). The relationship between primary school students' attitudes towards science and their science achievement (sampling: Izmir). *Journal of Educational Sciences*, *2*(6), 68-75.

Seymour, E., & Hewitt, N. (1997). *Talking about Leaving: Why do undergraduates leave the science*? Boulder, CO: Westview Press. USA.

Shaw, E. J., & Barbuti, S. (2010). Patterns of persistence in intended college major with a focus on STEM majors. *NACADA Journal, 30*(2), 19–34.

Shim, W. J., & Paik, S. (2014). The effects of high school track choice on students' postsecondary enrollment and majors in South Korea. *Asia Pacific Education Review*, *15*(4), 573-583.

Shin, J., Lee, H., McCarthy-Donovan, A., Hwang, H., Yim, S., & Seo, E. (2015). Home and motivational factors related to science-career pursuit: Gender differences and gender similarities. *International Journal of Science Education*, *37*(9), 1478-1503.

Shin, S., Lee, J. K., & Ha, M. (2017). Influence of career motivation on science learning in Korean high-school students. *EURASIA Journal of Mathematics Science and Technology Education, 13*(5), 1517-1538.

Shin, S., Rachmatullah, A., Ha, M., & Lee, J. K. (2018). A longitudinal trajectory of science learning motivation in Korean high school students. *Journal of Baltic Science Education*, *17*(4), 674-687.

Shumow, L., & Schmidt, J. A. (2013). Academic grades and motivation in high school science classrooms among male and female students: Associations with teachers' characteristics, beliefs and practices. *Journal of Education Research*, *7*(1), 53-71.

Sianou-Kyrgiou, E. (2010). Stratification in higher education, choice and social inequalities in Greece. *Higher Education Quarterly, 64*(1). 22-40.

Siegel, M. A., & Ranney, M. A. (2003). Developing the changes in attitude about the relevance of science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *40*(8), 757-775.

Simpson, J.C. (2001). Segregated differences by subject: Racial different in factors affecting academic major between European Americans, Asian Americans, and African, Hispanic, and Native Americans. *Journal of Higher Education*, *72*(1), 63-100.

Simon, R. A., Aulls, M. W., Dedic, H., Hubbard, K., & Hall, N. C. (2015). Exploring student persistence in STEM programs: a motivational model. *Canadian Journal of Education*, *38*(1), 1-27.

Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among Latino and Caucasian boys and girls. *Journal of Research in Science Teaching*, *52*(10), 1386-1407.

Simpson, R. D., & Oliver, J. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74*(1), 1-18.

Slife, B. D., & Williams, R. N. (1995). *What's behind the research?: Discovering hidden assumptions in the behavioral sciences*. Sage publication.

Smallbone, T., & Quinton, S. (2004). Increasing business students' confidence in questioning the validity and reliability of their research. *Electronic Journal of Business Research Methods*, *2*(2), 153-162.

Smart, J. C. (1985). Holland environments as reinforcement systems. *Research in Higher Education*, *23*(3), 279-292.

Smart, J. C., Feldman, K. A., & Ethington, C. A. (2000). *Academic disciplines: Holland's theory and the study of college students and faculty*. Vanderbilt University Press.

Song, C., & Glick, J.E. (2004). College attendance and choice of college majors among Asian-American students. *Social Science Quarterly, 85*(5), 1401-1421.

Sonnert, G. (2009). Parents who influence their children to become scientists: Effects of gender and parental education. *Social Study of Science*, *39*(6), 927-941.

Stearns, E., Bottía, M. C., Davalos, E., Mickelson, R. A., Moller, S., & Valentino, L. (2016). Demographic characteristics of high school math and science teachers and girls' success in STEM. *Social Problems*, *63*(1), 87-110.

Steffens, M. C., Jelenec, P., & Noack, P. (2010). On the leaky math pipeline: Comparing implicit math-gender stereotypes and math withdrawal in female and male children and adolescents. *Journal of Educational Psychology*, *102*(4), 947.

Stein, R. S. (2012). *Choosing science: a mixed-methods study of factors predicting Latino and Latina high school students' decisions to pursue science degrees* (Doctoral dissertation, Education). San Diego State University, California, United States of America.

Stokking, K. M. (2000). Predicting the choice of physics in secondary education. *International Journal of Science Education*, *22*(12), 1261-1283.

Strayhorn, T. L. (2015). Factors Influencing Black Males' Preparation for College and Success in STEM Majors: A Mixed Methods Study. *Western Journal of Black Studies*, *39*(1), 45-64.

Sweetland, S. R. (1996). Human capital theory: Foundations of a field of inquiry. *Review of Educational Research*, *66*(3), 341-359.

Tan, L. M., & Laswad, F. (2009). Understanding students' choice of academic majors: A longitudinal analysis. *Accounting Education: An International Journal*, *18*(3), 233-253.

Tenenbaum, H. R., & Leaper, C. (2003). Parent-child conversations about science: The socialization of gender inequities? *Developmental Psychology*, *39*(1), 34-47.

Tofel-Grehl, C., Callahan, C. M. (2014). STEM high school communities: Common and differing features. *Journal of Advanced Academics*, *25*(3), 237–271.

Tomei, A.; Dawson, E., & Dillon, J. (2013). A study of science, technology, engineering and mathematics education in United Kingdom [Report], Retrieved May 01, 2018, from https://acola.org.au/wp/stem-consultants- reports/.

Trusty, J. (2002). Effects of high school course-taking and other variables on choice of science and mathematics college majors. *Journal of Counseling & Development*, *80*(4), 464-474.

Trusty, J., Robinson, C., Plata, M., & Ng, K. (2000). Effects of gender, SES and early academic performance on postsecondary educational choice. *Journal of Counseling & Development, 78*(4), 463-472.

Turner, S.L., Steward, J.C., & Lapan, R.T. (2004). Family factors associated with sixth grade adolescents' math and science career interests. *The Career Development Quarterly, 53*, 41-52.

Ulicna, D., & Royale, R. (2015). Does the EU need more STEM graduates? (Report No. 120/01). Luxembourg, Danish Technological Institute.

Un, L. (2012). *A comparative study of education and development in Cambodia and Uganda from their civil wars to the present*, (Doctoral dissertation), University of Amsterdam.

Un, L., & Sok, S. (2016). *Higher education governance in Cambodia.* Education Research Council, Ministry of Education, Youth and Sport.

Un, L., & Sok, S. (2018). Higher education systems and institutions, Cambodia. *Higher Education*, *70*-80.

UNESCO National Education Support Strategy [UNESS]. (2010). *UNESCO educational support strategies.* UNESCO, Phnom Penh, Kingdom of Cambodia.

UNESCO. (2014). *World TVET database Cambodia.* UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training, Germany.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622-639.

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary Educational Psychology*, *34*(1), 89-101.

Van der Merwe, A. (2010). Does human capital theory account for individual higher education choice?. *International Business & Economics Research Journal (IBER)*, *9*(6), 81-94.

Ventura, F. (1992). Gender, science choice and achievement: a Maltese perspective. *School Science Review, 14*(4), 445-461.

Vooren, M., Haelermans, C., Groot, W., & van den Brink, H. M. (2019). *Does high school achievement predict success and enrolment in STEM higher education? An analysis using longitudinal Dutch register data*. [Report]. 1-30.

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081-1121.

Wang, X. (2017). Upward transfer in STEM fields of study: A new conceptual framework and survey instrument for institutional research. *New Directions for Institutional Research*, *170*, 49-60.

Wang, X., & Lee, S. Y. (2019). Investigating the psychometric properties of a new survey instrument measuring factors related to upward transfer in STEM fields. *The Review of Higher Education*, *42*(2), 339-384.

Wang, Z. (1995). *Factors affecting students career choice of science and engineering* (Unpublished Master's thesis). The University of British Columbia.

Ware, N. C., & Lee, V. E. (1988). Sex differences in choice of college science majors. *American Educational Research Journal*, *25*(4), 593-614.

Ware, N. C., Steckler, N. A., & Leserman, J. (1985). Undergraduate women: Who chooses a science major?. *The Journal of Higher Education*, *56*(1), 73-84.

Wei, X., Christiano, E. R., Jennifer, W. Y., Blackorby, J., Shattuck, P., & Newman, L. A. (2014). Postsecondary pathways and persistence for STEM versus non-STEM majors: Among college students with an autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(5), 1159-1167.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in science Teaching*, *32*(4), 387-398.

Weinrib, J. & Jones, G. (2013). *Canada's approach to Science, Technology, Engineering and Mathematics (STEM): Context, policy, strategy and programs.*

Welch, W. W. (1985). Research in science education: Review and recommendations. *Science Education*, *69*(3), 421-48.

Well, R.L., & Gaus, D. (1991). *Study of Kentucky middle school students' knowledge of career options* [Documentary Reproduction Service No. ED 351515]. ERIC.

Westrick, P., Radunzel, J., & Bassiri, D. (2018). *Leaning into STEM: Predicting STEM Major Choice Using Measures of Academic Tilt and Measured Interest Tilt*. [ACT Research & Policy. Technical Brief]. *ACT, Inc.*

Williamson, K., Given, L., & Scifleet, P. (2018). Qualitative data analysis. In K. Williamson & G. Johanson (Eds.), *Research methods: Information, systems, and contexts* (2nd ed., pp. 417-439). Tilde University Press.

Wiswall, M., Stiefel, L., Schwartz, A. E., Boccardo, J. (2014). Does attending a STEM high school improve student performance? Evidence from New York City. *Economics of Education Review*, *40*, 93–105.

Woessmann, L. (2009). International evidence on school tracking: A review. *CESifo DICE Report*, *7*(1), 26-34.

Woltman, H., Feldstain, A., MacKay, J. C., & Rocchi, M. (2012). An introduction to hierarchical linear modeling. *Tutorials in Quantitative Methods for Psychology, 8*(1), 52-69.

Woolnough, B. E. (1994a). Factors affecting students' choice of science and engineering. *International Journal of Science Education*, *16*(6), 659-676.

Woolnough, B. E., Guo, Y., Leite, M. S., Almeida, M. J. D., Ryu, T., Wang, Z., & Young, D. (1997). Factors affecting student choice of career in science and engineering: Parallel studies in Australia, Canada, China, England, Japan and Portugal. *Research in Science & Technological Education*, *15*(1), 105-121.

Woolnough, B.E. (1994b). *Effective science teaching.* Open University Press.

World Bank (2012). *Putting higher education to work: Skills and research for growth in East Asia*. World Bank, Washington, DC.

World Bank (November 2020). *Employment to population ratio for Cambodia* [SLEMPTOTLSPZSKHM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/SLEMPTOTLSPZSKHM, November 22, 2020.

World Economic Forum [WEF]. (2018). *"Employment Trend"*. Retrieved February 10, 2019 from http://reports.weforum.org/future-of-jobs-2016/employment-trends/.

Wu, S., Crespi, C. M., & Wong, W. K. (2012). Comparison of methods for estimating the intraclass correlation coefficient for binary responses in cancer prevention cluster randomized trials. *Contemporary Clinical Trials*, *33*(5), 869-880.

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual Review of Sociology*, *41*, 331-357.

Yara, P. O. (2009). Students attitude towards mathematics and academic achievement in some selected secondary schools in Southwestern Nigeria. *European Journal of Scientific Research*, *36*(3), 336-341.

Ye, R., Wells, R. R., Talkmitt, S., & Ren, H. (1998). *Student Attitudes toward Science Learning: A Cross-National Study of American and Chinese Secondary School Students* [Research Report]. ERIC.

Young, J. R., Ortiz, N., & Young, J. L. (2017). STEMulating interest: A meta-analysis of the effects of out-of-school time on student STEM interest. *International Journal of Education in Mathematics Science and Technology*, *5*(1), 62-74.

Zacharia, Z., & Barton, A. C. (2004). Urban middle‐school students' attitudes toward a defined science. *Science Education*, *88*(2), 197-222.

Zeng Z, Yao J, Gu H, Przybylki R (2018) A meta-analysis on the effects of STEM education on students' abilities. *Science Insight Education Frontiers, 1*(1), 3-16.

Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (STEM) across genders and grade levels. *Journal of Baltic Science Education*, *18*(3), 466.

Zuniga, K., Olson, J.K., & Winter, M. (2005). Science education for rural Latino/a students: Course placement and success in science. *Journal of Research in Science Teaching, 42*(4), 376-402.

APPENDICES

Appendix 1: STEM categorization and major fields of study

STEM Categorization	Major Field of Study	CIP Major List	Remarks
Natural Science	Agriculture, agriculture operations, and related sciences	- Agriculture, General - Agricultural business and management - Agricultural Mechanization - Agricultural Production Operations - Agricultural and Food Products Processing - Agricultural and Domestic Animal Services - Applied Horticulture and Horticultural Business Services - International Agriculture - Agricultural Public Services - Animal Sciences - Food Science and Technology - Plant Sciences - Soil Sciences - Agriculture, Agriculture Operations, and Related Sciences	
	Natural resources and conservation	- Natural Resources Conservation and Research - Natural Resources Management and Policy - Fishing and Fisheries Science and Management - Forestry - Wildlife and Wildlands Science and Management - Natural Resources and Conservation, other	
	Biological and biomedical sciences	- Biology, General - Biochemistry, Biophysics and Molecular Biology	

		- Botany/Plant Biology - Cellular Biology and Anatomical Sciences - Microbiological Sciences and Immunology - Zoology/Animal Biology - Genetics - Physiology, Pathology, and Related Sciences - Pharmacology and Toxicology - Biomathematics, Bioinformatics, and Computational Biology - Biotechnology - Ecology, Evolution, Systematics, and Population Biology - Molecular Medicine - Neurobiology and Neurosciences - Biological and Biomedical Sciences, other
	Physical science	- Physical Science - Astronomy and Astrophysics - Atmospheric Sciences and Meteorology - Chemistry - Geological and Earth Science/Geosciences - Physics - Material Science - Physical Sciences, other
	Science technologies and technicians	- Science Technologies/Technicians, General - Biology Technician/Biotechnology Laboratory Technician - Nuclear and Industrial Radiologic Technologies/Technicians

		- Physical Science Technologies/Technicians - Science Technologies/Technicians, other
Computer and information sciences	Computer and information sciences and support services	- Computer and Information Sciences, General - Computer Programming - Data Processing - Information Science/Studies - Computer Systems Analysis - Data Entry/Microcomputer Applications - Computer Science - Computer Software and Media Applications - Computer System Networking and Telecommunications - Computer/Information Technology Administration and Management - Computer and Information Sciences and Support Services, Others
Engineering and engineering technology	Engineering	- Engineering, General - Aerospace, Aeronautical and Astronautical Engineering - Agricultural Engineering - Architectural Engineering - Biomedical/Medical Engineering - Ceramic Sciences and Engineering - Chemical Engineering - Civil Engineering - Computer Engineering - Electrical, Electronics and Communications Engineering

	- Engineering Mechanics - Engineering Physics - Engineering Sciences - Environmental/Environmental Health Engineering - Material Engineering - Mechanical Engineering - Metallurgical Engineering - Mining and Mineral Engineering - Naval Architecture and Marines Engineering - Nuclear Engineering - Ocean Engineering - Petroleum Engineering - Systems Engineering - Textile Sciences and Engineering - Polymer/Plastics Engineering - Construction engineering - Forest Engineering - Industrial Engineering - Manufacturing Engineering - Geological/Geographical Engineering - Paper Science and Engineering - Electromechanical Engineering - Mechatronics, Robotics, and Automation Engineering - Biochemical Engineering - Engineering Chemistry - Biological/Biosystems Engineering

		- Engineering, Others
	Engineering technologies and engineering-related fields	- Engineering Technology, General - Architectural Engineering Technologies/Technicians - Civil Engineering Technologies/Technicians - Electrical Engineering Technologies/Technicians - Electromechanical Instrumentation and Maintenances Technologies - Environmental Control Technologies - Industrial Production Technologies - Quality Control and Safety Technologies - Mechanical Engineering Related Technologies - Mining and Petroleum Technologies - Construction Engineering Technologies - Drafting/Design Engineering Technologies - Nanotechnology
Mathematics	Mathematics and statistics	- Mathematics - Statistics - Practical Statistics Management - Practical Mathematics - Mathematics and Statistics, Other

Source: Synthesis of National Center for Education Statistics [NCES] (2020), Ministry of Education, Youth and Sport (2020), and extant literature on STEM majors in higher education.

Appendix 2: Survey questionnaire (English)

Code:……………….

SURVEY QUESTIONNAIRE

Name: ……………………………………….. Date of Birth: …………………………….

High School: ………………………………… Province: ………………………………….

Contact Number: …………………………….

Please fill in the questionnaire with your most honest answers. (This slip will be removed after data entry)

Code: ______________

SURVEY QUESTIONNAIRE

Dear Respondent,

My name is Sovansophal KAO, a doctoral student from Graduate School for International Development and Cooperation of Hiroshima University, Japan. I am conducting a study on Cambodian Upper Secondary School Students' Transition into Science, Technology, Engineering, and Mathematic (STEM) Majors in Higher Education of Cambodia. The main purpose of this study is to follow up on what factors influence the students' choice to stay in science/STEM or to move away from science/non-STEM majors when they transit from high school to higher education. This first step study is thus aiming to collect background information and demographic data of the sample. As the nature of the study suggests, your participation is crucially important to increase the proportion of human resource in STEM fields.

As to keep track of your identity, some personal information is requested. Yet, by any mean, this study DOES NOT intend to report the individual background. Rather, it will report only overall results and thus your response will be kept confidential and anonymous. Also, your participation is truly voluntary.

I am pleased that you are able to spend some time completing this questionnaire. Should you have any inquiries, you can contact me at 012 22 09 44. Thanks for your consideration.

Sincerely Yours,

Sovansophal KAO
A Doctoral Student in Division of Educational Development and Cultural and Regional Studies
Graduate School for International Development and Cooperation
Hiroshima University, Japan

I hereby truly understand the purpose of the study and **voluntarily** participate and offer the information as requested.

Signature: ____________________

Date: ____________________

STEM: Science, Technology, Engineering, and Mathematics (As independent and exclusive field)

Please kindly provide your most honest answers/responses to the following questions. Any of yo ur answer/response will be kept confidential and will be used for the overall analysis and to prese nt the overall results of the study ONLY. Your participation is truly voluntary.

I. Background Characteristics

Please kindly provide the following information. Circle the following answer choice or fill out the gap where it is necessary.

1. Sex 1. Male 2. Female

2. What is your place of origin? 1. Phnom Penh 2. Province: ………………

3. What stream are you taking for your high school certificate?

1. Science Stream 2. Social Stream

4. I discuss with my parents the choice of stream of study at high school.

1. Yes 2. No

5. What is the highest level of education do your parents want you to pursue?

1. Finish grade 12th 2. Associate degree 3. Bachelor's degree

4. Master's degree 5. Doctor degree

6. When you chose this stream, did you consider the major to pursue at higher education?

1. Yes. 2. No

II. Subject information

7. What is the highest level of your parents` education? (Circle one answer in each of the following options) (**1**=did not finish high school; **2**=completed high school; **3**=completed an associate degree; **4**=completed a bachelor's degree; **5**=completed a master's degree; **6**=completed a doctoral degree)

1. Father	1	2	3	4	5	6
2. Mother	1	2	3	4	5	6

8. Do your parents graduate in STEM related majors? (Science, Technology, Engineer…)

A. Father 1. Yes (Major: ………………….) 2. No

B. Mother 1. Yes (Major: ………………….) 2. No

9. Do your parents work in science related fields? (Science teacher, Engineer, Doctor…)

A. Father 1. Yes (Job: ………………….) 2. No

B. Mother 1. Yes (Job: ………………….) 2. No

10. Do you have any close relative working in STEM/science related jobs?

1. Yes (Job: ……………………) 2. No

11. What is your family`s monthly income?

1. Lower than 200 2. 200-400 $ 3. 400-600$ 4. 600$ up

12. Who earns the family income?

1. Father 2. Mother 3. Both parents

13. What is the status of your parents?

1. Married 2. Divorce/Dead

14. What subjects were you **good at** when you were at grade **10**? Please rank the subjects from number 1 to 5. (**1**=Poor, **2**=Average, **3**=Fairly good, **4**=Good, **5**=Excellent).

Subject	Rank	Subject	Rank
Mathematics		Khmer	
Physics		History	
Chemistry		Morality	
Biology		Geography	
Earth Science		English	

15. What is your **average score** or **grade** at grade **10** for the following subjects?

Subject	Score	Subject	Score
Mathematics		Khmer	
Physics		History	
Chemistry		Morality	
Biology		Geography	
Earth Science		English	

16. Do you do homework or self-studying? Please specify the number of hours spent doing studying or doing homework per week for each of the following subjects?

Subject	Hour	Subject	Hour
Mathematics		Biology	
Physics		Khmer	
Chemistry		Others……….	

17. Are you considering studying a major in STEM fields at university?

1. Definitely Yes 2. No

18. If you know that you are planning on major to study, please list below.

1. Major: ____________________________ 2. Do not know yet

19. For each of the following statements indicate the best answer that describe your **future plans in science**. (**1**= Strongly Disagree, **2**= Disagree, **3**=Neither, **4**= Agree, **5**= Strongly Agree). *5

No	Statement	SD	D	N	A	SA
1	I would like to study more science in the future.	1	2	3	4	5

2	I would like to study science related major at university	1	2	3	4	5
3	I would like to have a job working with science.	1	2	3	4	5
4	I would like to become a science teacher.	1	2	3	4	5
5	I would like to become a scientist.	1	2	3	4	5

20. Mathematics and science self-efficacy

This section sought to measure mathematics and science self-efficacy during your high school learning. Please rate the following statement.

(**1**= Strongly Unconfident, **2**= Unconfident, **3**=Neither, **4**= Confident, **5**= Strongly Confident)

No	Statement	SU	UC	N	C	SC
1	I can do excellent job on mathematics and science tests	1	2	3	4	5
2	I can understand difficult mathematics and science texts	1	2	3	4	5
3	I can understand difficult mathematics and science class	1	2	3	4	5
4	I can do excellent job on mathematics science assignments	1	2	3	4	5
5	I can master mathematics and science class skills	1	2	3	4	5
6	I can do well in courses related to science and engineering majors	1	2	3	4	5
7	I can do even the hardest work in science classes if I try	1	2	3	4	5
8	In science classes, even if the work is hard, I can learn it	1	2	3	4	5

21. Attitude towards Science

This section sought to measure student attitude toward science in general. Please rate the following statements. (**1**= Strongly Disagree, **2**= Disagree, 3=Neither, 4= Agree, **5**= Strongly Agree)

A. Learning science at school*

No	Statement	SD	D	N	A	SA
1	We learn interesting things in science lessons.	1	2	3	4	5
2	I look forward to my science lessons.	1	2	3	4	5
3	Science lessons are exciting.	1	2	3	4	5
4	I would like to do more science at school.	1	2	3	4	5
5	I like science better than most other subjects at school.	1	2	3	4	5
6	Science is interesting for me.	1	2	3	4	5

B. Self-concept in science

No	Statement	SD	D	N	A	SA
1	I find science difficult.	1	2	3	4	5
2	I am just good at science.	1	2	3	4	5

3	I get good marks in science.	1	2	3	4	5
4	I learn science quickly.	1	2	3	4	5
5	Science is one of my best subjects.	1	2	3	4	5
6	I feel confident when doing science.	1	2	3	4	5
7	In my science class, I understand everything.	1	2	3	4	5

C. Practical work in science

No	Statement	SD	D	N	A	SA
1	Practical work in science is exciting.	1	2	3	4	5
2	I like science practical work because you do not know what will happen.	1	2	3	4	5
3	Practical work in science is good because I can work with my friends.	1	2	3	4	5
4	I like practical work in science because I can decide what to do myself.	1	2	3	4	5
5	I would like more practical work in my science lessons.	1	2	3	4	5
6	We learn science better when we do practical work.	1	2	3	4	5
7	I look forward to doing science practical works.	1	2	3	4	5
8	Practical work in science is boring.	1	2	3	4	5

D. Science outside of school*

No	Statement	SD	D	N	A	SA
1	I have participated in science and mathematics club.	1	2	3	4	5
2	I have participated in science festival/STEM festival.	1	2	3	4	5
3	I have participated in the event on STEM bus.	1	2	3	4	5
4	I have participated in science and technology competition	1	2	3	4	5
5	I like watching science program on TV.	1	2	3	4	5
6	I like to visit science museum.	1	2	3	4	5
7	I would like to do more science activities outside of school.	1	2	3	4	5
8	I like reading science magazine and books.	1	2	3	4	5
9	It is exciting to learn about new things happening in science.	1	2	3	4	5

E. Importance of science and technology

No	Statement	SD	D	N	A	SA
1	Science and technology is important for society.	1	2	3	4	5
2	Science and technology make our lives easier and more	1	2	3	4	5

	comfortable.					
3	The benefits of science are greater that the harmful effects.	1	2	3	4	5
4	Science and technology are helping the poor.	1	2	3	4	5
5	There are many exciting things happening in science and technology.	1	2	3	4	5

22. Mathematics and Science Outcome Expectations

This section sought to measure students' outcome expectancy in math and science. Please rate the following statements from 1 to 5. (**1**= Strongly Disagree, **2**= Disagree, **3**=Neither, **4**= Agree, **5**= Strongly Agree)

No	Statement	SD	D	N	A	SA
1	If I take a lot of math course, then I will be better able to achieve my future goals.	1	2	3	4	5
2	If I learn math well, then I will be able to do lots of different types of careers.	1	2	3	4	5
3	If I take math course, then I will increase my grade point average.	1	2	3	4	5
4	If I do well in science classes, I will do well in high school	1	2	3	4	5
5	If I get good grade in math and science, my parents will be pleased.	1	2	3	4	5
6	If I get good grade in math and science, my friends will approve of me.	1	2	3	4	5
7	If I do well in math and science, I will be better prepared to go to college.	1	2	3	4	5

23. How often do you receive each of the following types of **support from your science and mathematics teachers** at school?

No	My science and mathematics teachers…	Never	Almost never	Some of the time	Most of the time	Almost always	Always
1	Care about me	1	2	3	4	5	6
2	Treat me fairly	1	2	3	4	5	6
3	Make it okay to ask questions	1	2	3	4	5	6
4	Explain things that I do not understand	1	2	3	4	5	6
5	Show me how to do things	1	2	3	4	5	6

6	Help me to solve problems by giving me information	1	2	3	4	5	6
7	Tell me I did a good job when I have done something well	1	2	3	4	5	6
8	Tell me nicely when I make mistakes	1	2	3	4	5	6
9	Tell me how to do well on tasks/assignments/ homework	1	2	3	4	5	6
10	Make sure I have what I need for class	1	2	3	4	5	6
11	Take time to help me learn the information well	1	2	3	4	5	6
12	Spend time with me when I need help	1	2	3	4	5	6

24. Indicate your level of agreement with each of the following statements concerning the use of these **specific practices in your science and mathematics classes**.

(1=Almost Never, 2=Sometimes, 3=Often, 4=Very Often)

No	Statement	AN	ST	OF	VOF
1	My teachers ask open-ended questions that make me think	1	2	3	4
2	My teachers ask me to give reasons for my answers	1	2	3	4
3	My teachers encourage me to ask questions	1	2	3	4
4	I talk to my classmates about how to solve problems	1	2	3	4
5	I repeat experiments to check results	1	2	3	4
6	I learn from my classmates	1	2	3	4
7	I use information to support my answers.	1	2	3	4

25. Indicate your level of agreement with each of the following statement concerning **encouragement to participate in science and mathematics** in school and possibly for a career. (**1**= Strongly Disagree, **2**= Disagree, **3**=Neither, **4**= Agree, **5**= Strongly Agree)

No	Statement	SD	D	N	A	SA
1	My parents/family encourage me to participate in science	1	2	3	4	5
2	My teachers encourage me to participate in science	1	2	3	4	5
3	My classmates/friends encourage me to participate in science	1	2	3	4	5
4	Female are encouraged to participate in science	1	2	3	4	5
5	Male students are encouraged to participate in science.	1	2	3	4	5

6	Society environment encourage me to participate in science.	1	2	3	4	5
7	I will be highly appreciated if I am majoring in one of science, technology, engineering, and mathematics fields.	1	2	3	4	5

26. Why do you choose to study in this study track? And why STEM major?

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27. Who encouraged you the most to choose this particular study track at high school? And STEM majors at higher education? How do they encourage?

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28. If you pursue your higher education, will you choose to major in Science, Technology, Engineering, and Mathematics (STEM) fields? Why? Why not?

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This is the end of the questionnaire.
Thanks for spending your valuable time to complete it.
Your active participation really contributes to the success of my study.
See you again.

Appendix 3: Survey questionnaire (Khmer Translation) *លេខកូដ៖*____________

កម្រងសំណួរស្រាវជ្រាវ

សួស្តីអ្នកចូលរួមទាំងអស់គ្នា!!!

*ខ្ញុំឈ្មោះ **កៅ សុវណ្ណសុផល** ជានិស្សិតថ្នាក់បណ្ឌិត នៅសាលាក្រោយឧត្តមសម្រាប់ការអភិវឌ្ឍអន្តរជាតិ និងសហប្រតិបត្តិការ នៃសាកលវិទ្យាល័យហ៊ីរ៉ូស៊ីម៉ា ប្រទេសជប៉ុន។ ខ្ញុំនឹងធ្វើការសិក្សាស្រាវជ្រាវមួយអំពី **ការបន្តការសិក្សារបស់សិស្សថ្នាក់វិទ្យាសាស្ត្រ ទៅចូលរៀនជំនាញក្នុងវិស័យវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា** **(STEM)** **នៅថ្នាក់ឧត្តមសិក្សា នៃប្រទេសកម្ពុជា**។ គោលបំណងសំខាន់នៃការសិក្សានេះគឺដើម្បីតាមដានអំពីកត្តា នានាដែលអាចជម្រុញនិស្សិតឱ្យសម្រេចចិត្តបន្តការសិក្សាជំនាញក្នុងវិស័យ* **STEM** *ឬក៏ផ្លាស់ទៅចូលរៀនជំនាញដែលមិនមែនជាវិស័យ* **STEM** *នៅពេលដែលគាត់បន្តការសិក្សាពីថ្នាក់វិទ្យាល័យទៅថ្នាក់ឧត្តមសិក្សា។ ការសិក្សាជំហ៊ានទី១ នេះគឺដើម្បីប្រមូលនូវព័ត៌មាន និងទិន្នន័យដែលអាចប្រែប្រួលតាមពេលវេលា ហើយនឹងអាចជះឥទ្ធិពល ដល់ការសម្រេចចិត្តជ្រើសរើសជំនាញសិក្សារបស់និស្សិត។ ដូចដែលលក្ខណៈនៃការសិក្សាបានបង្ហាញការចូលរួម របស់អ្នកទាំងអស់គ្នាពិតជាមានសារៈសំខាន់បំផុតដើម្បីចូលរួមបង្កើនចំនួននិស្សិតចូលរៀន ក៏ដូចជាធនធានមនុស្សក្នុងវិស័យ* **STEM** *សម្រាប់បំពេញតម្រូវការទីផ្សារការងារបច្ចុប្បន្ន។*

ដើម្បីតាមដាននូវអត្តសញ្ញាណរបស់អ្នកទាំងអស់គ្នា ព័ត៌មានផ្ទាល់ខ្លួនមួយចំនួននឹងត្រូវបានប្រមូល ប៉ុន្តែមិនថាក្នុងវិធីណាមួយ ការសិក្សានេះនឹងមិនរាយការណ៍នូវព័ត៌មានផ្ទាល់ខ្លួនរបស់អ្នកចូលរួមម្នាក់ៗនោះឡើយ។ ដើម្បីរក្សាការសម្ងាត់ដល់អ្នកដែលបានចូលរួមបំពេញកម្រងសំណួរ ការសិក្សានេះនឹងបង្ហាញតែលទ្ធផលរួមតែប៉ុណ្ណោះ។ ការចូល រួមរបស់អ្នកទាំងអស់គ្នាក៏ជាការស្ម័គ្រចិត្តផងដែរ។

ខ្ញុំពិតជាមានសេចក្តីរីករាយបំផុតដែលអ្នកទាំងអស់គ្នា បានចំណាយពេលវេលាដ៏មានតម្លៃដើម្បីបំពេញកម្រងសំណួរនេះ។ ប្រសិនបើអ្នកទាំងអស់គ្នាមានសំណួរអ្វីផ្សេងបន្ថែមទៀត សូមទំនាក់ទំនងមកខ្ញុំតាមរយៈទូរស័ព្ទលេខ ០១២/០៧០ ២២ ០៩ ៤៤។ សូមអរគុណសម្រាប់ការចូលរួមយ៉ាងសកម្មរបស់អ្នកទាំងអស់គ្នា។

ដោយក្តីរាប់អាន

កៅ សុវណ្ណសុផល
និស្សិតថ្នាក់បណ្ឌិតផ្នែកអភិវឌ្ឍន៍ការអប់រំ
សាកលវិទ្យាល័យហ៊ីរ៉ូស៊ីម៉ា ប្រទេសជប៉ុន

ខ្ញុំបានយល់ច្បាស់ពីគោលបំណងនៃការសិក្សា និងបានស្ម័គ្រចិត្តចូលរួមផ្តល់ព័ត៌មានទាំងឡាយដែលមាននៅក្នុងកម្រងសំណួរនេះ

ហត្ថលេខា ....

កាលបរិច្ឆេទ ....

សម្គាល់៖ **STEM** *សំដៅដល់មុខជំនាញដែលស្ថិតក្នុងវិស័យ* **(S)***វិទ្យាសាស្ត្រ* **(T)***បច្ចេកវិទ្យា* **(E)***វិស្វកម្ម និង* **(M)***គណិតវិទ្យា។ សូមមើលបញ្ជីមុខជំនាញ* **STEM** *មួយចំនួននៅទំព័របន្ទាប់។*

បញ្ជីមុខជំនាញមួយចំនួនដែលស្ថិតក្នុងវិស័យវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា(STEM)

(Some Majors in Science, Technology, Engineering and Mathematic, STEM related fields)

ល.រ	មុខជំនាញ	ល.រ	មុខជំនាញ
១	រូបវិទ្យា	២០	វិស្វកម្មកសិកម្ម
២	គីមីវិទ្យា	២១	គ្រឿងយន្តកសិកម្ម
៣	ជីវវិទ្យា	២២	វិស្វកម្មជីវសាស្ត្រ
៤	ផែនដីវិទ្យា	២៣	វិស្វកម្មបរិស្ថាន
៥	វិទ្យាសាស្ត្រកសិកម្ម	២៤	វិស្វកម្មអគ្គីសនី
៦	វិទ្យាសាស្ត្របរិស្ថាន	២៥	វិស្វកម្មសំណង់ស្ពានថ្នល់
៧	វិទ្យាសាស្ត្រកុំព្យូទ័រ	២៦	គ្រប់គ្រងសំណង់
៨	បច្ចេកវិទ្យាព័ត៌មាន	២៧	អេឡិចត្រូនិក
៩	ព័ត៌មានវិទ្យា	២៨	អគ្គិសនី និងអេឡិចត្រូនិក
១០	កម្មវិធីកុំព្យូទ័រ	២៩	ប្លង់ និងរចនា
១១	កុំព្យូទ័រពាណិជ្ជកម្ម	៣០	ស្ថាបត្យកម្ម
១២	កុំព្យូទ័រអនុវត្ត	៣១	ស្ថាបត្យកម្មផ្នែកខាងក្នុង
១៣	ទូរគមនាគមន៍	៣២	បច្ចេកវិទ្យាស្ថាបត្យកម្ម
១៤	គ្រប់គ្រងគេហទំព័រ	៣៣	គណិតវិទ្យា
១៥	តបណ្ដាញ	៣៤	គណិតវិទ្យាអនុវត្ត
១៦	ឧស្សាហកម្មមេកានិក	៣៥	ស្ថិតិវិទ្យា
១៧	មេកានិក	៣៦	គ្រប់គ្រងទិន្នន័យ
១៨	វិស្វកម្ម	៣៧	……………………
១៩	វិស្វកម្មស៊ីវិល	៣៨	……………………

<u>កំណត់ចំណាំ៖</u> ដើម្បីចូលរៀនមុខជំនាញក្នុងវិស័យ STEM នៅសាកលវិទ្យាល័យ ភាគច្រើនតម្រូវឱ្យសិស្សមានមូលដ្ឋានគ្រឹះច្រើនលើមុខវិជ្ជា គណិតវិទ្យា រូបវិទ្យា គីមីវិទ្យា ឬ ជីវវិទ្យា នៅថ្នាក់វិទ្យាល័យ។

សូមធ្វើការជ្រើសរើសមុខជំនាញប្រកបទៅដោយការពិចារណាខ្ពស់បំផុត!

សូមមេត្តាផ្តល់ព័ត៌មានដែលត្រឹមត្រូវ និងប្រកបដោយភាពស្មោះត្រង់អំពីអ្នក។ រាល់ចម្លើយនៃសំណួរនីមួយៗ នឹងត្រូវបានរក្សាទុកដោយត្រឹមត្រូវ និងសម្ងាត់បំផុតសម្រាប់ប្រើប្រាស់ក្នុងការវិភាគរកលទ្ធផលរួមនៃការសិក្សានេះតែប៉ុណ្ណោះ។

ក. ព័ត៌មានផ្ទាល់ខ្លួន៖

សូមផ្តល់នូវព័ត៌មានដូចខាងក្រោម ដោយធ្វើការគូសរង្វង់ជុំវិញចម្លើយ ឬ បំពេញចន្លោះក្នុងករណីចាំបាច់។

1. ភេទ ១. ប្រុស ២. ស្រី
2. ទីកន្លែងកំណើត ១. រាជធានីភ្នំពេញ ២. ខេត្ត.....................
3. តើអ្នករៀនថ្នាក់អ្វីនៅវិទ្យាល័យ? ១. ថ្នាក់វិទ្យាសាស្ត្រ ២. ថ្នាក់វិទ្យាសាស្ត្រសង្គម
4. តើអ្នកបានពិភាក្សាជាមួយឪពុកម្តាយដែរឬទេពេលអ្នកជ្រើសរើសថ្នាក់សិក្សានៅវិទ្យាល័យ?
   ១. បានពិភាក្សា ២. មិនបានពិភាក្សា
5. តើឪពុកម្តាយ/អាណាព្យាបាលរបស់អ្នកចង់ឱ្យអ្នករៀនបានខ្ពស់បំផុតត្រឹមកម្រិតណា?
   ១. បញ្ចប់ថ្នាក់វិទ្យាល័យ ២. បញ្ចប់ថ្នាក់បរិញ្ញាបត្ររង ៣. បញ្ចប់ថ្នាក់បរិញ្ញាបត្រ
   ៤. បញ្ចប់ថ្នាក់បរិញ្ញាបត្រជាន់ខ្ពស់ ៥. បញ្ចប់ថ្នាក់បណ្ឌិត
6. នៅពេលដែលអ្នកសម្រេចចិត្តចូលរៀនថ្នាក់វិទ្យាសាស្ត្រ ឬ ថ្នាក់វិទ្យាសាស្ត្រសង្គមនេះ តើអ្នកបានគិតដល់ជំនាញដែលអ្នកអាចនឹងបន្តការសិក្សានៅថ្នាក់សាកលវិទ្យាល័យដែរ ឬ ទេ?
   ១. បានគិតច្បាស់ ២. មិនបានគិតទេ

ខ. ព័ត៌មានផ្សេងៗ៖

7. តើឪពុកម្តាយរបស់អ្នកបានបញ្ចប់ការសិក្សាដល់កម្រិតណា? *សូមគូសរង្វង់ជុំវិញចម្លើយណាមួយក្នុងជម្រើសខាងក្រោម*
   (១=មិនបានបញ្ចប់ថ្នាក់វិទ្យាល័យ; ២=បញ្ចប់ថ្នាក់វិទ្យាល័យ; ៣=បញ្ចប់ថ្នាក់បរិញ្ញាបត្ររង; ៤=បញ្ចប់ថ្នាក់បរិញ្ញាបត្រ; ៥=បញ្ចប់ថ្នាក់បរិញ្ញាបត្រជាន់ខ្ពស់; ៦=បញ្ចប់ថ្នាក់បណ្ឌិត)
   ក. ឪពុក ១ ២ ៣ ៤ ៥ ៦
   ខ. ម្តាយ ១ ២ ៣ ៤ ៥ ៦
8. តើឪពុកម្តាយរបស់អ្នកបានបញ្ចប់ការសិក្សាលើវិស័យ STEM ដែរ ឬ ទេ? (គណិត រូប វិស្វកម្ម...)
   ក. ឪពុក ១. បាន (ជំនាញ: ....) ២. មិនបាន
   ខ. ម្តាយ ១. បាន (ជំនាញ: ....) ២. មិនបាន
9. តើឪពុកម្តាយរបស់អ្នកកំពុងបម្រើការងារក្នុងវិស័យ STEM ដែរ ឬ ទេ? (គ្រូគណិត រូប ពេទ្យ...)
   ក. ឪពុក ១. មាន (ការងារ: ....) ២. មិនមាន
   ខ. ម្តាយ ១. មាន (ការងារ: ....) ២. មិនមាន
10. តើអ្នកមានបងប្អូន សាច់ញាតិ កំពុងបម្រើការងារក្នុងវិស័យ STEM ឬ វិទ្យាសាស្ត្រដែរ ឬ ទេ?
    ១. មាន (ការងារ: ....) ២. មិនមាន
11. តើក្រុមគ្រួសាររបស់អ្នកអាចរកប្រាក់ចំណូលជាមធ្យមបានចំនួនប៉ុន្មានដុល្លារក្នុងមួយខែ?
    ១. តិចជាង ២០០ដុល្លារ ២. ពី ២០០-៤០០ដុល្លារ
    ៣. ពី ៤០០-៦០០ដុល្លារ ៤. ច្រើនជាង ៦០០ដុល្លារ
12. តើអ្នកណាជាអ្នករកចំណូលសម្រាប់គ្រួសារ?
    ១. ឪពុក ២. ម្តាយ ៣. អ្នកទាំងពីរ

13. តើឪពុកម្តាយរបស់អ្នករស់នៅជាមួយគ្នាដែរ ឬ ទេ?

១. រស់នៅជាមួយគ្នា ២. លែងលះ

14. នៅថ្នាក់ទី១០ តើអ្នកគិតថាអ្នករៀនមុខវិជ្ជាដូចខាងក្រោមបាន**ពូកែកម្រិតណា**? សូមបង់លេខ ១, ២, ៣, ៤, ឬ ៥ (១=ខ្សោយ; ២=មធ្យម; ៣=ល្អបង្គួរ; ៤=ល្អ; ៥=ល្អប្រសើរ) ក្នុងតារាងខាងក្រោម។

មុខវិជ្ជា	កម្រិតពូកែ	មុខវិជ្ជា	កម្រិតពូកែ
គណិតវិទ្យា		ភាសាខ្មែរ	
រូបវិទ្យា		ប្រវត្តិវិទ្យា	
គីមីវិទ្យា		សីលធម៌/ពលរដ្ឋវិទ្យា	
ជីវវិទ្យា		ភូមិវិទ្យា	
ផែនដីវិទ្យា		ភាសាបរទេស	

15. នៅថ្នាក់ទី១០ តើអ្នកបាន**ពិន្ទុមធ្យមភាគឆមាសទី១** ប៉ុន្មានសម្រាប់មុខវិជ្ជានីមួយៗដូចខាងក្រោម?

មុខវិជ្ជា	ពិន្ទុមធ្យមភាគឆមាសទី១	មុខវិជ្ជា	ពិន្ទុមធ្យមភាគឆមាសទី១
គណិតវិទ្យា		ភាសាខ្មែរ	
រូបវិទ្យា		ប្រវត្តិវិទ្យា	
គីមីវិទ្យា		សីលធម៌/ពលរដ្ឋវិទ្យា	
ជីវវិទ្យា		ភូមិវិទ្យា	
ផែនដីវិទ្យា		ភាសាបរទេស	

16. តើអ្នកបានចំណាយពេល**ចំនួនប៉ុន្មានម៉ោងក្នុងមួយសប្តាហ៍** សម្រាប់ការសិក្សានៅផ្ទះ ឬ ធ្វើកិច្ចការផ្ទះ (Homework, Assignment, Self-study) ក្នុងមុខវិជ្ជានីមួយៗដូចខាងក្រោម? ***សូមសរសេរចំនួនម៉ោងសរុបក្នុងមួយសប្តាហ៍។***

មុខវិជ្ជា	ចំនួនម៉ោងសរុប/សប្តាហ៍	មុខវិជ្ជា	ចំនួនម៉ោងសរុប/សប្តាហ៍
គណិតវិទ្យា		ភាសាខ្មែរ	
រូបវិទ្យា		ប្រវត្តិវិទ្យា	
គីមីវិទ្យា		ភូមិវិទ្យា	
ជីវវិទ្យា		មុខវិជ្ជាផ្សេងទៀត	

17. តើអ្នកនឹងបន្តការសិក្សាលើមុខជំនាញក្នុងវិស័យ **STEM** នៅសាកលវិទ្យាល័យដែរ ឬ ទេ?

១. ប្រាកដជារៀនក្នុងវិស័យនេះ ២. ប្រាកដជាអត់រៀន

18. ប្រសិនបើអ្នកបានពិចារណារួច តើអ្នកនឹងបន្តការសិក្សាលើជំនាញអ្វី? សូមបញ្ជាក់:

ជំនាញ: ______________________________

19. ខាងក្រោមនេះគឺចង់ដឹងពី**ផែនការនាពេលអនាគតលើផ្នែកវិទ្យាសាស្ត្រ**របស់អ្នក។ សូមគូសរង្វង់ជុំវិញ ចម្លើយដែលត្រឹមត្រូវបំផុតចំពោះអ្នកទៅតាមកម្រិតលេខដូចខាងក្រោម៖ (១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥= យល់ស្របខ្លាំងបំផុត[SA])*

ល.រ	ផែនការនាពេលអនាគតលើផ្នែកវិទ្យាសាស្ត្រ	SD	D	N	A	SA
១	ខ្ញុំចង់បន្តការសិក្សាលើផ្នែកវិទ្យាសាស្ត្របន្ថែមទៀតនាពេលអនាគត	១	២	៣	៤	៥
២	ខ្ញុំចង់បន្តការសិក្សាលើមុខជំនាញវិទ្យាសាស្ត្រ/STEM នៅសាកលវិទ្យាល័យ	១	២	៣	៤	៥
៣	ខ្ញុំចង់បម្រើការងារក្នុងវិស័យវិទ្យាសាស្ត្រ/STEM នាពេលអនាគត	១	២	៣	៤	៥
៤	ខ្ញុំចង់ក្លាយជាគ្រូបង្រៀនវិទ្យាសាស្ត្រ ឬគណិតវិទ្យានាពេលអនាគត	១	២	៣	៤	៥
៥	ខ្ញុំចង់ក្លាយជាអ្នកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥

20. **ភាពជឿជាក់លើសមត្ថភាពផ្ទាល់ខ្លួនក្នុងការសិក្សាមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ (Self-efficacy)** តើអ្នកមានភាពជឿជាក់លើសមត្ថភាពរបស់អ្នកក្នុងការសិក្សាមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ បានដល់កម្រិតណា? សូមគូសរង្វង់ជុំវិញលេខចម្លើយណាមួយដែលត្រឹមត្រូវបំផុតចំពោះអ្នក សម្រាប់ល្បះនីមួយៗ។

(១= មិនជឿជាក់ទាល់តែសោះ[SUC]; ២= មិនជឿជាក់[UC]; ៣=ធម្មតា[N]; ៤= ជឿជាក់[C]; ៥= ជឿជាក់ខ្លាំងបំផុត[SC]) ។

ល.រ	ភាពជឿជាក់លើសម្ថតភាពផ្ទាល់ខ្លួនក្នុងការសិក្សាមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ	SUC	UC	N	C	SC
១	ខ្ញុំអាច**ប្រឡង**មុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្របានពិន្ទុល្អប្រសើរ	១	២	៣	៤	៥
២	ខ្ញុំអាចយល់**អត្ថបទមេរៀន**លំបាកៗនៃមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្របានល្អប្រសើរ	១	២	៣	៤	៥
៣	ខ្ញុំអាចយល់**មេរៀន**លំបាកៗនៃមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្របានយ៉ាងងាយស្រួល	១	២	៣	៤	៥
៤	ខ្ញុំអាចធ្វើ**លំហាត់**(Assignment) នៃមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្របានល្អប្រសើរ	១	២	៣	៤	៥
៥	ខ្ញុំអាចមានភាពស្ទាត់ជំនាញ/ប្រសើរឡើងលើ**ជំនាញនានា**ទាក់ទងនឹងការសិក្សាមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្របាន	១	២	៣	៤	៥
៦	ខ្ញុំអាចរៀនបាន**ពិន្ទុ**ល្អលើមុខវិជ្ជានានាដែលជំនាញ STEM ត្រូវការ	១	២	៣	៤	៥
៧	ប្រសិនបើខ្ញុំខិតខំប្រឹងប្រែង ទោះបី**កិច្ចការ**ក្នុងមុខវិជ្ជាគណិតវិទ្យា និង វិទ្យាសាស្ត្រលំបាកយ៉ាងណាក៏ខ្ញុំអាចធ្វើបានដែរ	១	២	៣	៤	៥
៨	ប្រសិនបើខ្ញុំខិតខំប្រឹងប្រែង ទោះបី**មេរៀន**ក្នុងមុខវិជ្ជាគណិតវិទ្យា និង វិទ្យាសាស្ត្រលំបាកយ៉ាងណាក៏ខ្ញុំរៀនទាន់/យល់ដែរ	១	២	៣	៤	៥

21. **តើអ្នកមានឥរិយាបថយ៉ាងណាលើមុខវិជ្ជាវិទ្យាសាស្ត្រ? (Attitudes towards science)**

*ខាងក្រោមនេះគឺចង់ដឹងអំពី**ឥរិយាបថរបស់អ្នកលើមុខវិជ្ជាវិទ្យាសាស្ត្រ**។ សូមគូសរង្វង់ជុំវិញចម្លើយណាមួយដែលត្រឹមត្រូវបំផុតចំពោះអ្នក។*

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

ក. ការសិក្សាវិទ្យាសាស្ត្រនៅសាលា* (Learning science at school)

លរ	ការសិក្សាវិទ្យាសាស្ត្រនៅសាលា	SD	D	N	A	SA
១	ខ្ញុំរៀនមេរៀនដែលគួរឱ្យចាប់អារម្មណ៍ជាច្រើនក្នុងថ្នាក់វិទ្យាសាស្ត្រ	១	២	៣	៤	៥
២	ខ្ញុំរង់ចាំឱ្យតែដល់ម៉ោងដែលត្រូវរៀនមុខវិជ្ជាវិទ្យាសាស្ត្រទេ	១	២	៣	៤	៥
៣	មេរៀននៃមុខវិជ្ជាវិទ្យាសាស្ត្រគឺគួរឱ្យចាប់អារម្មណ៍ណាស់	១	២	៣	៤	៥
៤	ខ្ញុំចង់រៀនមេរៀនវិទ្យាសាស្ត្រឱ្យបានច្រើនបន្ថែមទៀតនៅសាលា	១	២	៣	៤	៥
៥	ខ្ញុំចូលចិត្តមុខវិជ្ជាវិទ្យាសាស្ត្រជាងមុខវិជ្ជាផ្សេងៗទៀតនៅសាលា	១	២	៣	៤	៥
៦	មុខវិជ្ជាវិទ្យាសាស្ត្រគឺពិតជាគួរឱ្យចាប់អារម្មណ៍ និងចង់រៀនណាស់	១	២	៣	៤	៥

ខ. ការយល់ឃើញអំពីខ្លួនអ្នក លើមុខវិជ្ជាវិទ្យាសាស្ត្រ (Self-concept in science)

តើអ្នកយល់យ៉ាងណាចំពោះមុខវិជ្ជាវិទ្យាសាស្ត្រ? សូមគូសរង្វង់ជុំវិញលេខចម្លើយណាមួយដែលត្រឹមត្រូវបំផុតចំពោះអ្នក ។

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

លរ	ការយល់ឃើញអំពីខ្លួនអ្នក លើមុខវិជ្ជាវិទ្យាសាស្ត្រ	SD	D	N	A	SA
១	ខ្ញុំយល់ថាមុខវិជ្ជាវិទ្យាសាស្ត្រ គឺជាមុខវិជ្ជាដែលលំបាក	១	២	៣	៤	៥
២	ខ្ញុំរៀនមុខវិជ្ជាវិទ្យាសាស្ត្រពូកែជាងមុខវិជ្ជាផ្សេងទៀត	១	២	៣	៤	៥
៣	ខ្ញុំតែងតែទទួលបានពិន្ទុល្អលើមុខវិជ្ជាវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៤	ខ្ញុំរៀនឆាប់យល់ពេលខ្ញុំរៀនមុខវិជ្ជាវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៥	មុខវិជ្ជាវិទ្យាសាស្ត្រ គឺជាមុខវិជ្ជាដែលខ្ញុំរៀនពូកែបំផុត	១	២	៣	៤	៥
៦	ខ្ញុំគិតថា ខ្ញុំមានភាពជឿជាក់ពេលខ្ញុំរៀនមុខវិជ្ជាវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៧	ក្នុងថ្នាក់រៀននៃមុខវិជ្ជាវិទ្យាសាស្ត្រ ខ្ញុំអាចយល់គ្រប់ចំណុចទាំងអស់	១	២	៣	៤	៥

គ. ការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រ (ពិសោធន៍)(Practical works in science class)

សូមគូសរង្វង់ជុំវិញលេខនៃចម្លើយដែលបញ្ជាក់ពីកម្រិតនៃការយល់ឃើញរបស់អ្នកចំពោះល្បះនីមួយៗ

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

លរ	ការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រ (ពិសោធន៍)	SD	D	N	A	SA
១	ការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រគឺពិតជាគួរឱ្យចាប់-អារម្មណ៍ណាស់	១	២	៣	៤	៥
២	ខ្ញុំចូលចិត្តការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រពីព្រោះខ្ញុំមិនដឹងថានឹងមានអ្វីនឹងកើតឡើងក្នុងការអនុវត្តនោះ	១	២	៣	៤	៥
៣	ការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រគឺល្អដោយសារខ្ញុំអាចធ្វើកិច្ចការជាមួយមិត្តភ័ក្ត្រដ៏ទៃទៀត	១	២	៣	៤	៥

៤	ខ្ញុំចូលចិត្តការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រពីព្រោះខ្ញុំអាចសម្រេចចិត្តធ្វើអ្វីដោយខ្លួនឯងបាន	១	២	៣	៤	៥
៥	ខ្ញុំចង់ឱ្យមានការអនុវត្តជាក់ស្តែងបន្ថែមទៀតក្នុងមេរៀននៃមុខវិជ្ជាវិទ្យាសាស្ត្ររបស់ខ្ញុំ	១	២	៣	៤	៥
៦	ខ្ញុំរៀនមុខវិជ្ជាវិទ្យាសាស្ត្របានល្អប្រសើរនៅពេលមេរៀននោះមានការអនុវត្តជាក់ស្តែង	១	២	៣	៤	៥
៧	ខ្ញុំរំពឹងរង់ចាំឱ្យតែដល់ម៉ោងអនុវត្តជាក់ស្តែងក្នុងម៉ោងវិទ្យាសាស្ត្រទេ	១	២	៣	៤	៥
៨	ការអនុវត្តជាក់ស្តែងក្នុងមុខវិជ្ជាវិទ្យាសាស្ត្រគឺគួរឱ្យធុញទ្រាន់ណាស់*	១	២	៣	៤	៥

ឃ. ការចូលរួមរបស់អ្នកក្នុងសកម្មភាពវិទ្យាសាស្ត្រនានានៅក្រៅសាលារៀន* (Science outside of school)

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

ល.រ	ការចូលរួមក្នុងសកម្មភាពវិទ្យាសាស្ត្រនានានៅក្រៅសាលារៀន	SD	D	N	A	SA
១	ខ្ញុំបានចូលរួមក្នុងក្លឹបសិក្សាវិទ្យាសាស្ត្រ និងគណិតវិទ្យា	១	២	៣	៤	៥
២	ខ្ញុំបានចូលរួមមហោស្រពវិទ្យាសាស្ត្រ (STEM Festival)	១	២	៣	៤	៥
៣	ខ្ញុំបានចូលរួមការចុះតាំងពិពរណ៍របស់រថយន្តស្ទែម (STEM Bus)	១	២	៣	៤	៥
៤	ខ្ញុំបានចូលរួម/មើលការប្រគួតប្រជែងផ្នែកវិទ្យាសាស្ត្រ (Robot)	១	២	៣	៤	៥
៥	ខ្ញុំចូលចិត្តមើលកម្មវិធីវិទ្យាសាស្ត្រដែលចាក់ផ្សាយតាមទូរទស្សន៍	១	២	៣	៤	៥
៦	ខ្ញុំចូលចិត្តមើលព័ត៌មានវិទ្យាសាស្ត្រតាមបណ្តាញសង្គមនានា	១	២	៣	៤	៥
៧	ខ្ញុំចង់ចូលរួមសកម្មភាពវិទ្យាសាស្ត្រនៅក្រៅសាលាច្រើនបន្ថែមទៀត	១	២	៣	៤	៥
៨	ខ្ញុំចូលចិត្តអានសៀវភៅ ព័ត៌មាន និងទស្សនាវដ្ដីវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៩	ខ្ញុំពិតជាស្ងប់ស្ងែងអំពីអ្វីដែលកើតឡើងក្នុងវិស័យវិទ្យាសាស្ត្រ	១	២	៣	៤	៥

ង. សារៈសំខាន់នៃវិទ្យាសាស្ត្រ និងបច្ចេកវិទ្យា (Importance of science and technology)

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

ល.រ	សារៈសំខាន់នៃវិទ្យាសាស្ត្រ និងបច្ចេកវិទ្យា	SD	D	N	A	SA
១	វិទ្យាសាស្ត្រ និងបច្ចេកវិទ្យាគឺពិតជាសំខាន់ណាស់សម្រាប់សង្គម	១	២	៣	៤	៥
២	វិទ្យាសាស្ត្រ និងបច្ចេកវិទ្យាធ្វើឱ្យជីវិតយើងងាយស្រួល និងមានផាសុកភាពជាងមុន	១	២	៣	៤	៥
៣	វិទ្យាសាស្ត្រមានអត្ថប្រយោជន៍ច្រើនជាងមានផលប៉ះពាល់	១	២	៣	៤	៥
៤	វិទ្យាសាស្ត្រ និងបច្ចេកវិទ្យាបានចូលរួមលើកកម្ពស់ជីវភាពរស់នៅរបស់ប្រជាជន	១	២	៣	៤	៥
៥	មានការរីកចម្រើនដែលគួរឱ្យចាប់អារម្មណ៍ជាច្រើនក្នុងវិស័យវិទ្យា-សាស្ត្រ និងបច្ចេកវិទ្យា	១	២	៣	៤	៥

22. *លទ្ធផលរំពឹងទុកក្នុងការសិក្សាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ* **(Math and science outcome expectations)**

(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥=យល់ស្របខ្លាំងបំផុត[SA])

ល.រ	លទ្ធផលរំពឹងទុកក្នុងការសិក្សាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ	SD	D	N	A	SA
១	ប្រសិនបើខ្ញុំរៀនគណិតវិទ្យាច្រើន ខ្ញុំនឹងអាចសម្រេចគោលដៅអនាគតខ្ញុំ	១	២	៣	៤	៥
២	ប្រសិនបើខ្ញុំរៀនគណិតវិទ្យាបានពូកែខ្ញុំអាចធ្វើការងារជាច្រើនប្រភេទបាន	១	២	៣	៤	៥
៣	ប្រសិនបើខ្ញុំរៀនគណិតវិទ្យា ខ្ញុំអាចបានបង្កើនពិន្ទុមធ្យមភាគបានច្រើន	១	២	៣	៤	៥
៤	ប្រសិនបើខ្ញុំរៀនមុខវិជ្ជាវិទ្យាសាស្ត្របានពូកែ ខ្ញុំនឹងរៀនពូកែនៅវិទ្យាល័យ	១	២	៣	៤	៥
៥	ប្រសិនបើនិទ្ទេសមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្ររបស់ខ្ញុំបានល្អ ឪពុកម្តាយរបស់ខ្ញុំនឹងសប្បាយចិត្ត	១	២	៣	៤	៥
៦	ប្រសិនបើនិទ្ទេសមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្ររបស់ខ្ញុំបានល្អមិត្ត-ភ័ក្ត្ររបស់ខ្ញុំនឹងចូលចិត្ត និងគាំទ្រខ្ញុំ	១	២	៣	៤	៥
៧	ប្រសិនបើខ្ញុំពូកែមុខវិជ្ជាគណិតវិទ្យា និងវិទ្យាសាស្ត្រ ខ្ញុំនឹងអាចចូលរៀននៅសាកលវិទ្យាល័យបានស្រួល	១	២	៣	៤	៥

23. តើអ្នកបានទទួល**ការគាំទ្រដូចខាងក្រោមពីគ្រូបង្រៀនវិទ្យាសាស្ត្រ និងគណិតវិទ្យា** *ញឹកញាប់កម្រិតណា?* *(១=មិនដែលទាល់តែសោះ[NV]; ២= ស្ទើរតែមិនដែល[AN]; ៣=ពេលខ្លះ[ST]; ៤= ភាគច្រើន[MT]; ៥=ស្ទើរតែគ្រប់ពេល[AA]; ៦=គ្រប់ពេល[AW])*

សូមគូសរង្វង់ជុំវិញលេខនៃចម្លើយដែលត្រឹមត្រូវបំផុតចំពោះអ្នក។

ល.រ	លោកគ្រូ/អ្នកគ្រូវិទ្យាសាស្ត្រ និងគណិតវិទ្យារបស់ខ្ញុំ...	NV	AN	ST	MT	AA	AW
១	យកចិត្តទុកដាក់លើការសិក្សារបស់ខ្ញុំ	១	២	៣	៤	៥	៦
២	ផ្តល់ភាពស្មើរគ្នាចំពោះខ្ញុំ និងសិស្សដទៃ	១	២	៣	៤	៥	៦
៣	បង្ករភាពងាយស្រួលឱ្យខ្ញុំសួរសំណួរនានាពេលរៀន	១	២	៣	៤	៥	៦
៤	ពន្យល់មេរៀនដែលខ្ញុំមិនយល់/យល់មិនច្បាស់	១	២	៣	៤	៥	៦
៥	បង្ហាញខ្ញុំពីរបៀបធ្វើកិច្ចការនានាក្នុងមុខវិជ្ជាគាត់	១	២	៣	៤	៥	៦
៦	ជួយខ្ញុំដើម្បីដោះស្រាយបញ្ហាដោយផ្តល់ព័ត៌មាននានាដល់ខ្ញុំ	១	២	៣	៤	៥	៦
៧	ផ្តល់ការសសើរដល់ខ្ញុំនៅពេលដែលខ្ញុំធ្វើការងារបានល្អ	១	២	៣	៤	៥	៦
៨	ណែនាំខ្ញុំដោយទន់ភ្លន់នៅពេលដែលខ្ញុំធ្វើអ្វីខុស	១	២	៣	៤	៥	៦
៩	ប្រាប់ខ្ញុំពីរបៀបធ្វើកិច្ចការក្នុងថ្នាក់ ឬ កិច្ចការផ្ទះ	១	២	៣	៤	៥	៦
១០	ធានាថាខ្ញុំមានអ្វីដែលខ្ញុំត្រូវការសម្រាប់ការសិក្សាមុខវិជ្ជានេះ	១	២	៣	៤	៥	៦
១១	ចំណាយពេលវេលាដើម្បីឱ្យខ្ញុំទទួលព័ត៌មានបានគ្រប់គ្រាន់	១	២	៣	៤	៥	៦
១២	ចំណាយពេលជាមួយខ្ញុំនៅពេលដែលខ្ញុំត្រូវការ	១	២	៣	៤	៥	៦

24. ខាងក្រោមនេះគឺជា**ការអនុវត្តមួយចំនួនក្នុងថ្នាក់នៃមុខវិជ្ជាវិទ្យាសាស្ត្រ និងគណិតវិទ្យា**។ *សូមគូសរង្វង់ជុំវិញលេខនៃចម្លើយដែលបញ្ជាក់ពីកម្រិតនៃការយល់ឃើញរបស់អ្នកចំពោះល្បះនីមួយៗ។* <u>(១=ស្ទើរតែមិនដែលសោះ[AN]; ២=ពេលខ្លះ [ST]; ៣=ភាគច្រើន[OF]; ៤=គ្រប់ពេល[VOF])</u>

ល.រ	ការអនុវត្តក្នុងថ្នាក់នៃមុខវិជ្ជាវិទ្យាសាស្ត្រ និងគណិតវិទ្យា	AN	ST	OF	VOF
១	លោកគ្រូ/អ្នកគ្រូសួរសំណួរបើក(សំណួររកព័ត៌មានបន្ថែម)ដើម្បីឱ្យខ្ញុំគិត	១	២	៣	៤
២	លោកគ្រូ/អ្នកគ្រូឱ្យខ្ញុំផ្តល់មូលហេតុដែលគាំទ្រចម្លើយរបស់ខ្ញុំ	១	២	៣	៤
៣	លោកគ្រូ/អ្នកគ្រូលើកទឹកចិត្តឱ្យខ្ញុំសួរសំណួរបន្ថែម	១	២	៣	៤
៤	ឱ្យខ្ញុំពិភាក្សាជាមួយមិត្តរួមថ្នាក់ដើម្បីស្វែងរកវិធីដោះស្រាយបញ្ហា	១	២	៣	៤
៥	ឱ្យខ្ញុំធ្វើពិសោធន៍ដើម្បីផ្ទៀងផ្ទាត់លទ្ធផល/ទ្រឹស្តីដែលបានសិក្សា	១	២	៣	៤
៦	ឱ្យខ្ញុំអាចរៀនពីមិត្តភក្តិរបស់ខ្ញុំបន្ថែមពីការសិក្សាពីពួកគាត់	១	២	៣	៤
៧	ឱ្យខ្ញុំប្រើប្រាស់ព័ត៌មាននានាដើម្បីគាំទ្រចម្លើយរបស់ខ្ញុំ	១	២	៣	៤

25. ខាងក្រោមនេះគឺជា**ការលើកទឹកចិត្តឱ្យអ្នកចូលរួមសិក្សាមុខវិជ្ជាវិទ្យាសាស្ត្រ និងគណិតវិទ្យា**។ *សូមគូសរង្វង់ជុំវិញលេខដែលបញ្ជាក់ពីកម្រិតនៃការយល់ឃើញរបស់អ្នក* <u>(១= មិនយល់ស្របទាល់តែសោះ[SD]; ២= មិនយល់ស្រប[D]; ៣=ធម្មតា[N]; ៤= យល់ស្រប[A]; ៥= យល់ស្របខ្លាំងបំផុត[SA])</u>។

ល.រ	ការលើកទឹកចិត្តឱ្យចូលរួមសិក្សាមុខវិជ្ជាវិទ្យាសាស្ត្រ និងគណិតវិទ្យា	SD	D	N	A	SA
១	ឪពុកម្តាយរបស់ខ្ញុំបានលើកទឹកចិត្តខ្ញុំឱ្យចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
២	លោកគ្រូ/អ្នកគ្រូរបស់ខ្ញុំបានលើកទឹកចិត្តខ្ញុំឱ្យចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៣	មិត្តរួមថ្នាក់របស់ខ្ញុំបានលើកទឹកចិត្តខ្ញុំឱ្យចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៤	សិស្សនារីត្រូវបានលើកទឹកចិត្តឱ្យចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៥	សិស្សប្រុសត្រូវបានលើកទឹកចិត្តឱ្យចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៦	បរិយាកាសសង្គមបង្ករលក្ខណៈឱ្យខ្ញុំចង់ចូលរៀនផ្នែកវិទ្យាសាស្ត្រ	១	២	៣	៤	៥
៧	សង្គមនឹងឱ្យតម្លៃខ្ពស់ដល់ខ្ញុំប្រសិនបើខ្ញុំជ្រើសរើសសិក្សាជំនាញដែលស្ថិតក្នុងវិស័យវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា(STEM)	១	២	៣	៤	៥

26. តើអ្នកយល់ថាការសិក្សានៅថ្នាក់វិទ្យាសាស្ត្រ ឬ ថ្នាក់វិទ្យាសាស្ត្រសង្គម នៅវិទ្យាល័យបានផ្តល់លទ្ធភាព និងសមត្ថភាពឱ្យអ្នកអាចបន្តការសិក្សាលើមុខជំនាញវិទ្យាសាស្ត្រ/ STEM នៅសាកលវិទ្យាល័យដែរ ឬ ទេ?

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27. *តើអ្នកគិតថាបរិយាកាសនៅជុំវិញអ្នក (ក្រុមគ្រួសារ វិទ្យាល័យ និងកត្តាផ្សេងៗទៀត) បានជម្រុញទឹកចិត្ត ឬ បង្អាក់ទឹកចិត្តអ្នកក្នុងការចង់បន្តការសិក្សាលើជំនាញក្នុងវិស័យវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា* **(STEM)** *កម្រិតណា?*

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28. *ប្រសិនបើអ្នកបន្តការសិក្សាទៅកម្រិតឧត្តមសិក្សា តើអ្នកនឹងបន្តការសិក្សាលើជំនាញក្នុងវិស័យវិទ្យា-សាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា* **(STEM)** *ដែរ ឬ ទេ? ហេតុអ្វី?*

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សូមអរគុណចំពោះការចូលរួមយ៉ាងសកម្មរបស់អ្នកទាំងអស់គ្នាក្នុងការសិក្សានេះ
ការចូលរួមមួយនេះពិតជាមានសារៈសំខាន់ និងបានចូលរួមចំណែកយ៉ាងច្រើនបំផុតក្នុងការសិក្សាស្រាវជ្រាវមួយនេះ។
ជូនពរអ្នកទាំងអស់គ្នាទទួលបាននូវជោគជ័យក្នុងការសិក្សា និងជីវិតការងារនាពេលអនាគត។

Appendix 4: School checklist (English)

CODE: ____________

1. Type of school A. Normal B. New Generation C. Technical General
2. School within the campus: A. Upper secondary B. Lower and upper secondary
3. Number of students in the academic year 2019-2020…………….…………………….
4. Number of grades 11th students: Science: …………… Social Science: …………...
5. How many classes and grade 12th students in this school in this academic year?

Track	**Number of class**	**Number of students**
Science		
Social Science		

6. Average number of students in each class?

……..…………………………………………………………………………………

7. Number of shifts and period implemented in the school?

A. One shift B. Two shifts B. Three shifts

8. Number of upper secondary school/female teachers? …………………………………...
9. Number of science teachers/female teachers? …………………………………...
10. Number of mathematics teachers/female teachers? ………………………………..…
11. Qualifications of science and mathematics teachers in the target classes?

Subject	**Class 12……**		**Class 12……**		**Class 12……**	
	Qualification	Experience	Qualification	Experience	Qualification	Experience
Mathematics						
Physics						
Chemistry						
Biology						
Earth Science						

12. Have science and mathematics teachers participated in training or workshop to build their professionalism in the last 3 years? A. Yes B. No
13. How often is the technical subject group meeting conducted per month? Purpose?

………………………………………………………………………………………

14. Has the school orientated the students in choosing the science or social science track?

A. Yes B. No

15. Has the school orientated the students in choosing academic majors in higher education?

A. Yes B. No

Appendix 5: Online semi-structure interview protocol (English)

I. INTRODUCTION

1. Statement of Purpose:

Today discussion is on your aspiration of academic major and reflection on your upper secondary school experience. This discussion is part of a research study to better understand factors involved with students either choosing or not choosing to pursue science, technology, engineering, and mathematics (STEM) majors in Cambodia.

2. Confidentiality:

Your responses and opinions are very important. There are no right or wrong answers to any of these questions. I am simply seeking your opinions. In order to accurately reflect our conversation, I will be recording this online interview. The results will be used to generalize students' beliefs, so you will not be identified individually. Keep in mind that it is important that you do not mention names when talking about yourself, or other people including teachers; just share with me your experiences at upper secondary school. Furthermore, it is important that we all agree to keep ideas from the discussion private, so please do not share anything with other. I will keep what I hear confidential, so please do so yourselves. I encourage you to be open and honest with your opinions, but you can always choose to not answer a question if you feel uncomfortable.

3. Time Frame:

This online interview will be about 60 minutes.

4. Participation:

Before we begin, feel free to ask me any question. Again, once we start you can always choose to leave the discussion if you feel uncomfortable.

II. QUESTIONS:

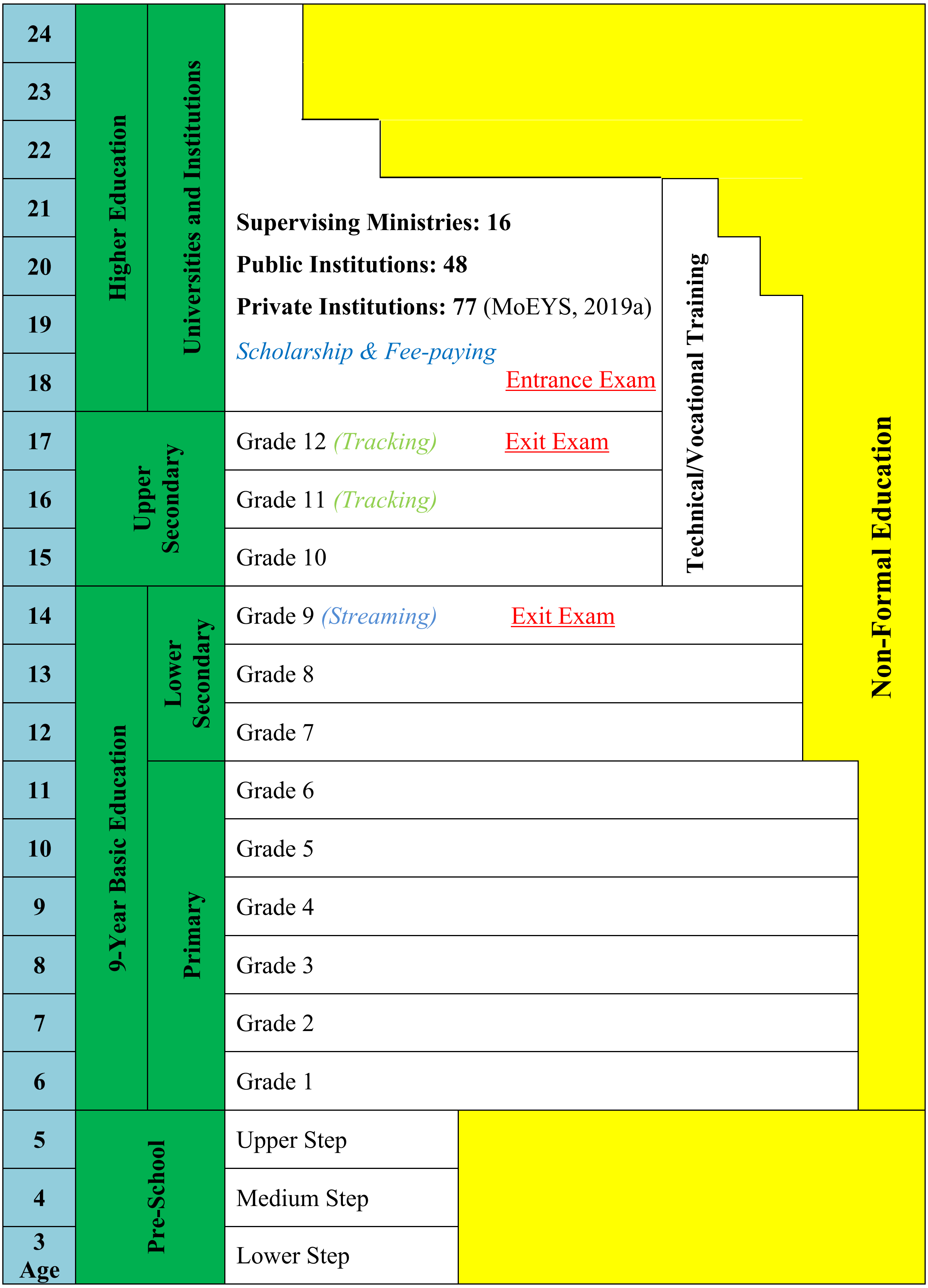
1. What are your plans after upper secondary school? Is there anything in particular that pushed you towards this track?
2. Which track are you taking at upper secondary school? What experiences/factors helped you decide to take this track? (Differentiate for students who are taking science or social science in terms of science and mathematics hours)

3. Have any of your friends, teachers, family, or relative ever said anything to you about being in particular track? (for girls: Did you receive any messages about girls studying science?)
4. How do you feel about studying science and math at upper secondary school? (good attitudes versus poor attitudes towards science, anything memorable that has pushed you towards this feeling?) Do you feel that this is the same or different from other students in your classes?
5. Do you feel that you are good at science and math? Can you do well if you try?
6. Thinking back to your science and math lessons, is there anything memorable about how you were taught that may have either increased or decreased your interest in science? learning of science? Activities that you did/did not enjoy?
7. Thinking back to your science and math learning setting, is there anything memorable about your relationship with your science and math teachers? (in terms of support for learning, expectations for you as a student, motivate you that make you feel that you will be successful). Specifically, what has the teacher done or not done to make you feel this way?
8. If you were able to control what happens in science and math lessons, what would you do to improve interactions and students' experiences?
9. How do you feel about science outside of school? Have you participated in any science-related activities? (like science clubs, camps, STEM festival, STEM bus)?
10. Here are some statistics about student in science…. In 2017-2018, about 60% of the students are in the science track but in higher education fewer than 30% are taking STEM related majors.
    - Why do you think so few science tack students pursue STEM majors at university? Is there anything that you would like to suggest so as to change this phenomenon?

III. CONCLUSION:

Would you like to follow up on any of the topics we have discussed? Thank you for your participation. If you have any more information that you feel would be useful for my study that you would like to add, feel free to contact me. Additionally, if you are interested in learning about the results of my study, please let me know, and I will send you a link to my dissertation when it is complete.

Appendix 6: Education system in Cambodia



Appendix 7: Data collection administrative documents

- *Permission to MoEYS from academic supervisor (pilot survey)*

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PHONE +81-82-424-6906 FAX +81-82-424-6904

IDEC

Japan, June 27, 2018

Dear Sir or Madam,

I am writing this letter to seek your permission to allow Mr. KAO SOVANSOPHAL to conduct his pilot research survey at your institution.

Mr. KAO SOVANSOPHAL has been a doctoral student of Educational Development in the Graduate School for International Development and Cooperation (IDEC), Hiroshima University since April 2018. For his doctoral dissertation, he plans to conduct a study on the Cambodian students' transition into higher education Science, Technology, Engineering and Mathematics (STEM) majors. The study aims to find out the policy initiatives, contextual supports, and individual motivations influencing students in their decisions to move from science track at high school level into or away from STEM related majors in higher education. This research study can contribute a great deal to the policy of the Ministry of Education, Youth and Sport (MoEYS) to enhance the students' uptake and to improve the human resource development in STEM field to meet the country economic development trend.

According to the nature of the study, the main data source from students regarding their choices of majors will be the primary target. As such, to collect the first wave of data, the researcher has developed the questionnaire measuring the students' choice of science and social science tracks at high school and their preliminary level of individual motivations and contextual supports to majoring in STEM. Through the collected data, the researcher strongly believes to validate his research instrument which would be formally used in the next data collection schedule. With a wide range of data, I strongly hope that his study will provide useful and relevant inputs into the endeavor of Cambodian Government to develop human resource in STEM field. Also, it will provide useful reference points for further research on students' transition from high school to higher education level, particularly STEM field, in the developing context like that of Cambodia.

Therefore, as his academic advisor, I would like to ask you to grant permission to KAO SOVANSOPHAL to conduct his pilot study at your institution.

If you wish further information and questions, please feel free to contact me.

Faithfully Yours,

Kinya Shimizu, PhD
Professor, Graduate School for International Development and Cooperation (IDEC)
Hiroshima University, Japan
kiyas@hiroshima-u.ac.jp

- *Permission from Department of Higher Education, MoEYS (Pilot)*

ព្រះរាជាណាចក្រកម្ពុជា
ជាតិ សាសនា ព្រះមហាក្សត្រ
*****

ក្រសួងអប់រំ យុវជន និងកីឡា
នាយកដ្ឋានឧត្តមសិក្សា
លេខៈ ០៣៤.........ឧស

ថ្ងៃ [illegible] ខែបឋមាសាឍ ឆ្នាំច សំរឹទ្ធិស័ក ព.ស២៥៦២
រាជធានីភ្នំពេញ ថ្ងៃទី១០ ខែកក្កដា ឆ្នាំ២០១៨

ជម្រាបជូន
លោក/លោកស្រីនាយកវិទ្យាល័យ..

កម្មវត្ថុៈ សំណើសុំការអនុញ្ញាតឱ្យ លោក កៅ សុវណ្ណសុផល អនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សាចុះប្រមូលទិន្នន័យសាកល្បងសម្រាប់សរសេរនិក្ខេបបទថ្នាក់បណ្ឌិត។

យោងៈ លិខិតរបស់លោកសាស្ត្រាចារ្យ **គីនយ៉ា ស៊ីម៉ីហ្សឺ** ចុះថ្ងៃទី២៧ ខែមិថុនា ឆ្នាំ២០១៨

តបតាមកម្មវត្ថុ និងយោងខាងលើ ខ្ញុំសូមជម្រាបជូន លោក/លោកស្រី នាយកថា **លោក កៅ សុវណ្ណសុផល** ជាអនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សា បានទទួលអាហារូបករណ៍សិក្សាថ្នាក់បណ្ឌិត នៅសាកលវិទ្យាល័យហ៊ីរ៉ូស៊ីម៉ា នៃប្រទេសជប៉ុន សម្រាប់ឆ្នាំសិក្សា២០១៨-២០២១។ ដើម្បីសរសេរនិក្ខេបបទបញ្ចប់ការសិក្សា លោកមានគម្រោងសិក្សាស្រាវជ្រាវអំពី **កត្តាដែលជម្រុញដល់ការសម្រេចចិត្តរបស់សិស្សថ្នាក់វិទ្យាល័យ ឱ្យជ្រើសរើសចូលរៀនមុខជំនាញវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា (STEM) នៅកម្រិតឧត្តមសិក្សា**។ ដើម្បីទទួលបាននូវទិន្នន័យសម្រាប់ការស្រាវជ្រាវខាងលើ លោកនឹងត្រូវធ្វើការស្ទង់មតិសាកល្បងមួយ **(Pilot Survey)** ជាមួយសិស្សដែលបាននឹងកំពុងសិក្សាថ្នាក់វិទ្យាសាស្ត្រ និងថ្នាក់វិទ្យាសាស្ត្រសង្គម នៃថ្នាក់ទី១១ ដោយប្រើកម្រងសំណួរដូចមានជូនភ្ជាប់ និងប្រមូលនូវលទ្ធផលសិក្សាប្រចាំឆ្នាំ តាមមុខវិជ្ជាក្នុងថ្នាក់ទី១០ របស់ពួកគាត់ផងដែរ។ ការស្រាវជ្រាវនេះមានរយៈពេល **១៣ថ្ងៃ ដោយគិតចាប់ពីថ្ងៃទី១០ ខែកក្កដា ដល់ថ្ងៃទី២២ ខែកក្កដា ឆ្នាំ២០១៨**។

អាស្រ័យដូចបានជម្រាបជូនខាងលើ សូមលោក/លោកស្រីនាយកមេត្តាពិនិត្យលទ្ធភាព និងអនុញ្ញាត ឱ្យ លោក កៅ សុវណ្ណសុផល បានចុះសិក្សាស្រាវជ្រាវ និងប្រមូលទិន្នន័យសម្រាប់សរសេរនិក្ខេបបទបញ្ចប់ការ សិក្សាដោយអនុគ្រោះ។

សូមលោក/លោកស្រី នាយក ទទួលនូវការរាប់អានអំពីខ្ញុំ

ប្រធាននាយកដ្ឋានឧត្តមសិក្សា

គង់_ភូមីភា

ទំនាក់ទំនងៈ
លោក កៅ សុវណ្ណសុផល
ទូរស័ព្ទៈ [illegible]

- *Permission to MoEYS from academic supervisor (first wave data collection)*

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IDEC

Japan, October 29, 2018

Dear Sir or Madam,

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kiyas@hiroshima-u.ac.jp

- *Permission from Department of Higher Education, MoEYS (first wave data collection)*

ព្រះរាជាណាចក្រកម្ពុជា
ជាតិ សាសនា ព្រះមហាក្សត្រ

ក្រសួងអប់រំ យុវជន និងកីឡា
នាយកដ្ឋានឧត្តមសិក្សា
លេខ:..១៣៧..ឧស

ថ្ងៃ.................ខែអស្សុជ ឆ្នាំច សំរឹទ្ធិស័ក ព.ស.២៥៦២
រាជធានីភ្នំពេញ ថ្ងៃទី.....២៧.....ខែវិច្ឆិកា ឆ្នាំ២០១៨

ជម្រាបជូន
លោក/លោកស្រី នាយក នាយិកា វិទ្យាល័យ.................................

កម្មវត្ថុ៖ សំណើសុំការអនុញ្ញាតឱ្យ **លោក កៅ សុវណ្ណសុផល** អនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សា ចុះប្រមូលព័ត៌មាន និងទិន្នន័យសម្រាប់សរសេរនិក្ខេបបទថ្នាក់បណ្ឌិត ។
យោង៖ លិខិតរបស់ **លោកសាស្ត្រាចារ្យ ស៊ីនយ៉ា ស៊ីម៉ុងហ្វ្រី** ចុះថ្ងៃទី២៩ ខែតុលា ឆ្នាំ២០១៨ ។

តបតាមកម្មវត្ថុ និងយោងខាងលើ ខ្ញុំសូមជម្រាបលោក/លោកស្រី នាយក នាយិកាជ្រាបថា៖ **លោក កៅ សុវណ្ណសុផល** អនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សា បានទទួលអាហារូបករណ៍សិក្សាថ្នាក់បណ្ឌិតនៅសាកលវិទ្យាល័យហ៊ីរ៉ូស៊ីម៉ា នៃប្រទេសជប៉ុនសម្រាប់ឆ្នាំសិក្សា២០១៨-២០២១។ លោកមានគម្រោងសិក្សាស្រាវជ្រាវអំពី**កត្តាដែលជះឥទ្ធិពលដល់ការសម្រេចចិត្តរបស់សិស្សថ្នាក់វិទ្យាល័យឱ្យជ្រើសរើសចូលរៀនមុខជំនាញ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា** (STEM) **នៅកម្រិតឧត្តមសិក្សា** ដើម្បីសរសេរនិក្ខេបបទបញ្ចប់ការសិក្សាថ្នាក់បណ្ឌិត។ ក្នុងន័យនេះ ដើម្បីទទួលបាននូវទិន្នន័យ និងព័ត៌មានសម្រាប់ការស្រាវជ្រាវខាងលើ លោកត្រូវធ្វើការសម្ភាសន៍ជាមួយសិស្ស ដែលកំពុងសិក្សាថ្នាក់វិទ្យាសាស្ត្រ និងថ្នាក់វិទ្យាសាស្ត្រសង្គម នៃថ្នាក់ទី១១ ដោយប្រើកម្រងសំណួរដូចមានជូនភ្ជាប់ និងប្រមូលនូវលទ្ធផលសិក្សាប្រចាំឆ្នាំតាមមុខវិជ្ជាក្នុងថ្នាក់ទី១០ របស់ពួកគាត់ផងដែរ។ ការស្រាវជ្រាវនេះមានរយៈពេល **៣ថ្ងៃ ដោយគិតចាប់ពីថ្ងៃទី២៦ ខែវិច្ឆិកា ដល់ថ្ងៃទី២៨ ខែធ្នូ ឆ្នាំ២០១៨**។

អាស្រ័យដូចបានជម្រាបជូនខាងលើ សូមលោក/លោកស្រី នាយក នាយិកា មេត្តាពិនិត្យលទ្ធភាព និងអនុញ្ញាតឱ្យ លោក កៅ សុវណ្ណសុផល បានចុះសិក្សាស្រាវជ្រាវប្រមូលព័ត៌មាន និងទិន្នន័យសម្រាប់សរសេរនិក្ខេបបទបញ្ចប់ការសិក្សាដោយអនុគ្រោះ។

សូមលោក/លោកស្រី នាយក នាយិកា ទទួលនូវការគោរពរាប់អានពីខ្ញុំ

ប្រធាននាយកដ្ឋានឧត្តមសិក្សា

គង់_គុម៉ីរ៉ា

ចម្លងជូន
-[illegible]
-ដើម្បីជ្រាបជាព័ត៌មាន-
-កាលប្បវត្តិ
-ឯកសារ ក.ឧស

លេខទំនាក់ទំនង លោក កៅ សុវណ្ណសុផល ០១២០៣៧០ ២២ ០៩ ៨៨

- *Permission to MoEYS from academic supervisor (second wave data collection)*

HIROSHIMA UNIVERSITY
Graduate School for International Development and Cooperation

Japan, May 16, 2019

Dear Sir or Madam,

I am writing this letter to seek your permission to allow Mr. KAO SOVANSOPHAL to conduct his second wave research survey at your institution.

Mr. KAO SOVANSOPHAL has been a doctoral student of Educational Development in the Graduate School for International Development and Cooperation (IDEC), Hiroshima University since April 2018. For his doctoral dissertation, he plans to conduct a longitudinal study on the Cambodian students' transition into higher education Science, Technology, Engineering and Mathematics (STEM) majors. The study aims to find out the policy initiatives, contextual supports, and individual motivations influencing students' decisions to move from science track at upper secondary school level into or away from STEM related majors in higher education of Cambodia. This research study can contribute a great deal to the policy of the Ministry of Education, Youth and Sport (MoEYS) in enhancing the students' uptake and in improving the human resource development in STEM fields to meet the country economic development trend.

According to the nature of the study, the main data source from students regarding their choices of majors will be the primary target. As such, to collect the second wave data, the researcher will be repeatedly measuring the students' changes influenced by science and social science tracks at high school, individual motivations, and contextual supports on the persistent to majoring in STEM. Through this procedure, the researcher strongly believes to collect trustworthy data which could be used for the analysis and for the final wave data collection comparison. With a wide range of data, I strongly hope that his study will provide useful and relevant inputs into the endeavor of Cambodian Government to develop human resource in STEM fields. Also, it will provide useful literature for further research on students' transition from upper secondary school to higher education, particularly STEM fields, in the developing context like that of Cambodia.

Therefore, as his academic advisor, I would like to ask you to grant permission to Mr. KAO SOVANSOPHAL to conduct his second wave data collection at your institution.

If you wish further information and questions, please feel free to contact me.

Faithfully Yours,

Kinya Shimizu, PhD
Professor, Graduate School for International Development and Cooperation (IDEC)
Hiroshima University, Japan
kiyas@hiroshima-u.ac.jp

- *Permission from Department of Higher Education, MoEYS (second wave data collection)*

ព្រះរាជាណាចក្រកម្ពុជា
ជាតិ សាសនា ព្រះមហាក្សត្រ

ក្រសួងអប់រំ យុវជន និងកីឡា
នាយកដ្ឋានឧត្តមសិក្សា
លេខៈ ០៨៦ នស

ថ្ងៃ សុក្រ ៥កើត ខែជេស្ឋ ឆ្នាំកុរ ឯកស័ក ព.ស ២៥៦៣
រាជធានីភ្នំពេញ ថ្ងៃទី ០៧ ខែមិថុនា ឆ្នាំ២០១៩

ជម្រាបជូន

លោក/លោកស្រី នាយក នាយិកា វិទ្យាល័យ..............................

កម្មវត្ថុ៖ សំណើសុំការអនុញ្ញាតឱ្យ **លោក កៅ សុវណ្ណសុផល** អនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សា ចុះប្រមូលព័ត៌មាន និងទិន្នន័យសម្រាប់សរសេរនិក្ខេបបទថ្នាក់បណ្ឌិត។

យោង៖ លិខិតរបស់ **លោកសាស្ត្រាចារ្យ គីនយ៉ា ស៊ីម៉ីហ្ស៊ី** ចុះថ្ងៃទី១៦ ខែឧសភា ឆ្នាំ២០១៩។

តបតាមកម្មវត្ថុ និងយោងខាងលើ ខ្ញុំសូមជម្រាបលោក/លោកស្រី នាយក នាយិកាជ្រាបថា៖ **លោក កៅ សុវណ្ណសុផល** ជាអនុប្រធានការិយាល័យចុះឈ្មោះចូលរៀន នៃនាយកដ្ឋានឧត្តមសិក្សា បានទទួលអាហារូបករណ៍ថ្នាក់បណ្ឌិតទៅសិក្សានៅសាកលវិទ្យាល័យហ៊ីរ៉ូស៊ីម៉ា នៃប្រទេសជប៉ុន សម្រាប់ឆ្នាំសិក្សា២០១៨-២០២១។ លោកមានគម្រោងសិក្សាស្រាវជ្រាវរយៈពេលវែងមួយអំពី **កត្តាដែលជំរុញដល់ការសម្រេចចិត្តរបស់សិស្សថ្នាក់វិទ្យាល័យឱ្យជ្រើសរើសចូលរៀនមុខជំនាញវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា វិស្វកម្ម និងគណិតវិទ្យា (STEM) នៅកម្រិតឧត្តមសិក្សា** ដើម្បីសរសេរនិក្ខេបបទបញ្ចប់ការសិក្សាថ្នាក់បណ្ឌិត។ ក្នុងន័យនេះ ដើម្បីទទួលបាននូវទិន្នន័យ និងព័ត៌មាន សម្រាប់ការស្រាវជ្រាវខាងលើ លោកត្រូវធ្វើការស្ទង់មតិជាលើកទី២ ជាមួយសិស្សបាននិងកំពុងសិក្សាថ្នាក់ទី១១ (ដូចមានបញ្ជីជូនភ្ជាប់) និងសូមទិន្នន័យនៃលទ្ធផលសិក្សាតាមមុខវិជ្ជា សម្រាប់ឆមាសទី១ ដោយផ្អែកលើសៀវភៅសិក្ខាគារិករបស់ពួកគាត់។ ការចុះសិក្សាស្រាវជ្រាវនេះមានរយៈពេល **៣៥ថ្ងៃ ដោយគិតចាប់ពី ថ្ងៃទី២៣ ខែមិថុនា ដល់ថ្ងៃទី២៧ ខែកក្កដា ឆ្នាំ២០១៩។**

អាស្រ័យដូចបានជម្រាបជូនខាងលើ សូមលោក/លោកស្រី នាយក នាយិកា មេត្តាពិនិត្យលទ្ធភាព និងអនុញ្ញាតឱ្យ លោក កៅ សុវណ្ណសុផល បានចុះសិក្សាស្រាវជ្រាវប្រមូលព័ត៌មាន និងទិន្នន័យសម្រាប់សរសេរនិក្ខេបបទបញ្ចប់ការសិក្សាដោយអនុគ្រោះ។

សូមលោក/លោកស្រី នាយក នាយិកា ទទួលនូវការរាប់អានអំពីខ្ញុំ

ប្រធាននាយកដ្ឋានឧត្តមសិក្សា

គង់_តូមីកា

ចម្លងជូន៖
- អគ្គនាយកដ្ឋានឧត្តមសិក្សា
- មន្ទីរអប់រំ យុវជន និងកីឡា រាជធានី/ខេត្តពាក់ព័ន្ធ
  "ដើម្បីជ្រាបជាព័ត៌មាន"
- កាលប្បវត្តិ
- ឯកសារ នាយកដ្ឋានឧត្តមសិក្សា

លេខទំនាក់ទំនង៖ លោក កៅ សុវណ្ណសុផល ០១២/០៧០ ២២ ០៩ ៥៥

- *Permission to MoEYS from academic supervisor (field research check)*

HIROSHIMA UNIVERSITY

Japan, May 16, 2019

Dear Sir or Madam,

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According to the nature of the study, the main data source from students regarding their choices of majors will be the primary target. As such, to collect the second wave data, the researcher will be repeatedly measuring the students' changes influenced by science and social science tracks at high school, individual motivations, and contextual supports on the persistent to majoring in STEM. Through this procedure, the researcher strongly believes to collect trustworthy data which could be used for the analysis and for the final wave data collection comparison. With a wide range of data, I strongly hope that his study will provide useful and relevant inputs into the endeavor of Cambodian Government to develop human resource in STEM fields. Also, it will provide useful literature for further research on students' transition from upper secondary school to higher education, particularly STEM fields, in the developing context like that of Cambodia.

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Faithfully Yours,

Kinya Shimizu, PhD
Professor, Graduate School for International Development and Cooperation (IDEC)
Hiroshima University, Japan
kiyas@hiroshima-u.ac.jp

Appendix 8: Example list of higher education majors and oriented subjects

No.	Academic Major	Oriented subjects	Grade Required
1	Mathematics	1. Mathematics 2. Physic	A—E
2	Physics	1. Mathematics 2. Physic	A—E
3	Chemistry	1. Chemistry 2. Mathematics	A—E
4	Biology	1. Biology 2. Chemistry	A—E
5	Earth and environmental science	1. Biology 2. Chemistry	A—E
6	Agricultural science	1. Biology 2. Chemistry	A—E
7	Agricultural engineering	1. Mathematics 2. Biology 3. Chemistry	A—E
8	Bioengineering	1. Mathematics 2. Biology	A—E
9	Information technology	1. Mathematics 2. Physic	A—E
10	Animal science	1. Biology 2. Chemistry	A—E
11	Engineering	1. Mathematics 2. Chemistry 3. Physics	A—E
12	Mechanic	1. Mathematics 2. Physics	A—E
13	Mathematics	1. Mathematics 2. Physics	A—E
14	Law	1. History 2. Khmer	A—E
15	Public administration	1. History 2. Khmer	A—E
17	Tourism	1. History 2. Geography	A—E
18	English	1. English 2. Khmer	A—E
19	…		

Sources: MoEYS (2020a)

Note: Grade (A=Excellent, B=Good, C=Fairly Good, D=Average, E=Poor, F=Failed)

Appendix 9: Map of Cambodia and selected research sites

Remarks:

▲: Selected research sites

Appendix 10: Curriculum vitae

I. Personal Information:

Latin Name:	Sovansophal KAO
Date of Birth:	15 July 1984
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II. Academic Qualifications:

2018 – Present:	Pursuing doctoral degree in Educational Development at Graduate School for International Development and Cooperation, Hiroshima University.
2011 – 2013:	Master of Arts in Educational Development from Graduate School for International Development and Cooperation, Hiroshima University.
2009 – 2012:	Master of Education in Educational Planning and Management from Royal University of Phnom Penh.
2003 – 2007:	Bachelor of Education in Teaching English as a Foreign Language from Institute of Foreign Languages, Royal University of Phnom Penh.

III. Published Peer-Reviewed Journal Articles:

- Kao, S. (2019). Cambodian upper secondary school students' attitudes towards science: Trends and patterns. *Journal of International Development and Cooperation*, *26*(1), 15–27.
- Kao, S. (2019). Family socioeconomic status and students' choice of STEM majors: evidence from higher education of Cambodia. *International Journal of Comparative Education and Development, 22*(1), 49–65.
- Kao, S., & Shimizu, K. (2019). Factors affecting students' choice of science and engineering majors in higher education of Cambodia. *International Journal of Curriculum Development and Practice, 21*(1), 69–82.
- Kao, S., & Shimizu, K. (2020). A review on STEM enrollment in higher education of Cambodia: Current status, issues, and implication of initiatives. *Journal of International Development and Cooperation*. *26*(2), 123–134.
- Kao, S., & Shimizu, K. (2020). Factors affecting Cambodian upper secondary school students' choice of science track. *International Journal of Sociology of Education, 9*(3), 262–292.

IV. Academic Conference Presentations:

- Kao, S. (2018). A review on STEM enrollment in higher education of Cambodia: Current status, issue, and implication of initiatives. Presented at the Japan Society for Science Education 42nd Annual Meeting (from 17th to 19th August 2018) at Shinshu University, Nagano (Education) Campus, Japan.

- Kao, S. (2018). Factors affecting students' choice of science and engineering majors in higher education of Cambodia. Presented at the 44th National congress of the Japanese Society of Teacher Education (from 8th to 9th September 2018) at Nippon Sport Science University (Setagaya Campus), Japan.
- Kao, S. (2018). Individual characteristics and choice of science and engineering majors in higher education of Cambodia. Presented at the 19th International Conference of Educational Research (from 17th to 19th October 2018) at Seoul National University (Hoam Faculty House), South Korea.
- Kao, S. (2019). Cambodian upper secondary school students' attitudes towards sciences: Trends and patterns. Presented at the Japan Society for Science Education 43rd Annual Meeting (from 23rd to 25th August 2019) at Utsunomiya University, Japan.
- Kao, S. (2019). Factors affecting Cambodian upper secondary school students' choice of science track. Presented at the 6th JASID Western Japan Research Meeting (on 27th August 2019) at Kyushu University, Japan.
- Kao, S. (2019). Factors affecting Cambodian upper secondary school students' choice of science track. Presented at the 45th National congress of the Japanese Society of Teacher Education (from 13th to 14th October 2019) at Aichi University of Education, Japan.
- Kao, S. (2020). STEM education and longitudinal methods in education research. Presented at the Environmental and Science Education Webinar Series (ESEWS) #1 (conducted online on May 29th, 2020), Universitas Negeri Semarang, Indonesia.
- Kao, S. (2020). Effects of tracking and other variables on Cambodian upper secondary school students' aspirations of STEM majors: Multilevel analysis. Presented at the 7th JASID Western Japan Research Meeting (conducted online on 21st August 2020), Hiroshima University, Japan.

V. Academic Award:

December 18, 2019: Hiroshima University Excellent Student Award