

# A Review on STEM Enrollment in Higher Education of Cambodia: Current Status, Issues, and Implications of Initiatives

Sovansopha KAO

Graduate Student

Graduate School for International Development and Cooperation

Hiroshima University

1-5-1 Kagamiyama, Higashi Hiroshima, 739-8529, Japan

sovansopha@gmail.com

Kinya SHIMIZU

Professor

Graduate School for International Development and Cooperation

Hiroshima University

1-5-1 Kagamiyama, Higashi Hiroshima, 739-8529, Japan

kinyas@hiroshima-u.ac.jp

## Abstract

STEM (Science, Technology, Engineering, and Mathematics) education has received priority in the policy agendas of many countries around the world. As Cambodia is undergoing a shift in her economic development trends in this regional and global industrial revolution 4.0, it has been emphasized that the nation has a great demand for graduates in STEM fields. However, currently the country faces critical challenges in enhancing the uptake of students into these fields in higher education. This paper, thus, was aimed to present the current status of students' enrollment in STEM majors, discuss key issues Cambodia is facing, and draw implications of policy initiatives from five OECD nations to enhance students' enrollment in STEM fields in higher education. The results of the review suggested that to increase students' uptake into STEM majors in higher education, not only classroom level but also extracurricular initiatives should be taken into consideration at the upper secondary schools as well as society.

## 1. Introduction

Capacity Building and Human Resource Development has become the first “growth rectangle” of the “Rectangular Strategy” Phase III of the Royal Government of Cambodia [RGC] (RGC, 2013a). Under this rectangle, the RGC has set “strengthening and enhancing education, science and technology and technical training” as one of its highest priorities to support Cambodia's new economic development trend. In compliance with this strategy and to ensure consistency in terms of hierarchy, coherence, and synchronization between the Rectangular Strategy Phase III and “National Strategic Development Plan [NSDP] Updated 2014–2018” of the Royal Government of Cambodia (RGC, 2014), Ministry of Education, Youth and Sport (MoEYS) has launched its “Education Strategic Plan [ESP] 2014–2018”, with a continued focus on three main policy objectives, one of which is to ensure equitable access to all education services (MoEYS, 2014a; 2014b).

From the economic development perspective, Cambodia was traditionally an agriculture-based country 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 focused on three more pillars: garments, tourism, and construction. Recently, the Fourth Cambodian Economic Forum on “Cambodian Economy in Post-Crisis Environment: Industrial Development Policy Options toward a Sustainable Economic Development” has strongly emphasized on the strategic vision of the RGC in shifting the country economic development from dependence on agriculture, garments, tourism, and construction to a broad-based industrial and technology-oriented economy in order to move the country to a higher-middle income country by 2030 and a high-income country

in 2050 (RGC, 2015).

Accordingly, Science, Technology, Engineering, and Mathematics (STEM) Education Policy (MoEYS, 2016a) was developed. The policy emphasized that as Cambodia is a developing country with a growing economy, its inhabitants need to be encouraged to explore the demand of 21<sup>st</sup> century skills and thus produce more human resource in STEM fields in order to move the Cambodian 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 (UNESCO National Education Support Strategy [UNESS], 2010; Asian Development Bank [ADB], 2011; Un & Sok, 2016). Consequently, MoEYS, as also stated in the ESP 2014–2018, politically aims to increase the overall enrollment in STEM fields in both public and private higher education institutions (MoEYS, 2014a). However, according to the statistics compiled by the Department of Higher Education (DHE), MoEYS, the percentage of student enrollment in these fields still remains low. In short, according to the Cambodian Development Resource Institute [CDRI], (2015) and MoEYS (2017), despite higher market demand likely to transform and modernize Cambodia's industrial sector by 2025, not many students are enrolling in STEM related fields but rather in non-STEM fields.

There is lack of globally accepted definition of STEM education and 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, NSF also employed STEM as an acronym for broad fields of study at higher education (Green, 2007). In the same token, the current study, thus, adopted STEM acronym to represent the group of majors at higher education. In a broad definition, STEM majors include not only the common categories of mathematics, natural sciences, engineering, and computer and information sciences, but also such social/behavioral sciences as psychology, economics, sociology, and political science. However, many recent efforts are aimed at improving STEM education mainly in mathematics, natural sciences, engineering, and technologies. For this reason, this study excluded social/behavioral sciences from STEM majors. Thus, STEM fields include mathematics, natural sciences (including physical sciences and biological/agricultural sciences), engineering/engineering technologies, and computer/information sciences (Chen, 2013; Chen & Weko, 2009; Crisp et al., 2009; Green, 2007; MoEYS, 2009; 2016b; Ulicna & Royale, 2015). In the other continuum, non-STEM fields in this study, include social/behavioral sciences, humanities, business, education, economic, and management (Chen, 2013; MoEYS, 2009; 2016b; Ulicna & Royale, 2015).

A number of challenges in STEM enrollment should be identified and solved so as to meet the needs of relevant stakeholders in initiating any policy objectives to ensure that STEM education, especially in higher education, proceeds or will proceed smoothly for the sustainable inclusive development of the country in this era of the fourth industrial revolution. In practice, in order to respond to this demand for graduates in science, technology, engineering, and mathematics (STEM) as well as the Industrial Development Policy (IDP) 2015–2025 and National Strategic Development Plan (NSDP) 2014–2018 of the Royal Government of Cambodia, it is indispensable to examine the current status of STEM enrollment in higher education, to examine the respective contextual issues, and to identify policy initiatives to overcome them. In light of the paucity of evidence-based approach initiatives, this paper therefore delineates the current status of STEM enrollment in higher education of Cambodia, identifies current development, elicits issues of concern, and draws policy implications from five Organization for Economic Cooperation and Development [OECD] Nations (Canada, France, Japan, the United Kingdom, and the United States) to enhance students' uptake in STEM fields in higher education of Cambodia. Ultimately, this will help with the implementation of Industrial Development Policy of RGC. To be more specific, this review has two-fold specific objectives.

1. To review the current status and issues of students' uptake from science track at upper secondary school into STEM majors in higher education of Cambodia.
2. To synthesize the policy initiatives drawn from the five OECD countries to enhance Cambodian students' uptake from upper secondary school into STEM fields in higher education.

## 2. Research Method

Overall, this study employed a comprehensive review of policy documents, reports, and articles dated within this last decade. To achieve the first objective, that is to understand the current status and issues of students' participation in science, technology, engineering, and mathematics (STEM) in the higher education of Cambodia, researchers analyzed key data sources including the STEM Education Policy, educational reports, and educational statistics compiled by Ministry of Education, Youth and Sport, and other significant extant literature from other development partners published within this last decade. To analyze these qualitative data, an analytical framework of the students' transition from the science track in upper secondary school into STEM fields in higher education was developed.

To achieve the second review objective, the researchers desk-reviewed, analyzed, compared, and synthesized existing policy documents and literatures discussing specifically the policy initiatives implemented to promote students' understanding and to enhance their matriculation from science track at upper secondary school into STEM fields in higher education, the so-called 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 the STEM: Country Comparison 2013 report on Canada (Weinrib & Jones, 2013), France (Oliveira & Roberts, 2013), Japan (Ishikawa et al., 2013), the United Kingdom (Tomei et al., 2013), and the United States of America (Maltse et al., 2013) and educational policies and practices across the world in STEM and Science Education in Europe: National Policies, Practices, and Research (Freeman et al., 2015). These STEM Country Comparison Reports were the synthesis of the extant studies and reports on the respective countries. These literatures, thus, provided a holistic understanding of the situation and policy initiatives of those comparator countries.

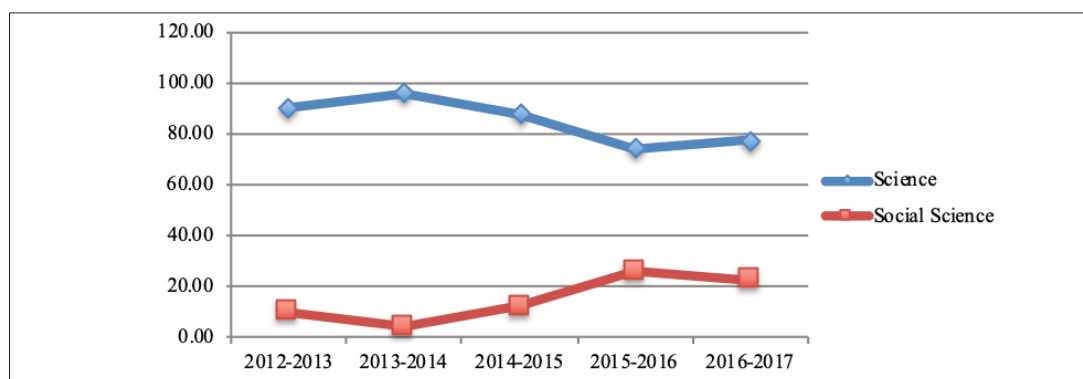
To synthesize these initiatives, thematic analysis of secondary data was used to identify recurrent themes drawing out themes of interest to this integrative review—policy initiatives to enhance students' uptake in STEM fields in higher education of each comparator country. Inductive analysis was performed allowing for pattern themes and categories to arise out of the data. The themes of policy initiatives from the comparator countries were then categorized into the main emerging themes (Bryman, 2016; Creswell & Poth, 2017).

There were three main justifications for selecting the five afore-mentioned comparator countries. First, by definition in STEM: Country Comparison Reports, these comparator countries 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), which was in congruence with the classification of STEM fields in the Cambodian context. Second, based on the share of tertiary graduates in STEM and gender distribution in 2015 database compiled by the Organization for Economic Cooperation and Development [OECD] (OECD, 2017), France and the United Kingdom, whose share of tertiary graduates in STEM fields was above the OECD average, and Canada, Japan, and the United States with shares below OECD average, were selected to be the comparator countries. Lastly, all of the selected countries have experienced and overcome effectively with the issue of the decline of students' interest in and negative attitudes towards science and participation in STEM fields as the countries transitioned to another stage of industrial development (Marginson et al., 2013). Thus, the policy initiatives from these countries would provide clues for policy initiatives and interventions in the context of Cambodia.

### 3. Results and Discussion

#### 3.1 Current Status

The examination of the current status of STEM in higher education in this review focuses on the extent of students' preparation in upper secondary school and their uptakes (push-pull perspective) into higher education of Cambodia. From the pushing perspective, in order to build a strong background competence in science and mathematics in upper secondary school and to provide more orientated pathways for choosing academic majors in higher education, MoEYS has implemented a tracking system since 2010 (MoEYS, 2010). This bifurcation required all grade 11<sup>th</sup> students to choose either the science or social science track. While the focus of the former track is on science subjects (physics, chemistry, biology, earth and environmental science) and mathematics, the focus of the latter track is on Khmer literature, history, geography, and moral studies. Statistically, since the beginning of its implementation, the science track has attracted more interests among Cambodian students than has the social science track.



**Figure 1.** Percentage of students in the science and social science tracks at upper secondary schools of Cambodia  
**Source:** Statistics compiled by Department of General Education from 2011-2017, MoEYS (2017)

As shown in Figure 1, nearly 80% of upper secondary school students chose the science track while the share of students in the social science track only reached about 20% in the last couple of academic years, (MoEYS, 2017). Reflecting with the trend of the economic development as well as the Industrial Development Policy of the RGC, this higher share of the students in science track at upper secondary school indicated a very good match with the current need of the human resource and the effort of MoEYS to increase the share of students in science track and to enhance their enrollment in STEM related majors in higher education. Yet, whether this science track students stay in or swing away from STEM fields in higher education is a concern among educational practitioners and policy makers.

In the regulation, the differences between these two tracks (science and social science) laid in the core focus subjects and the number of teaching hours, content focus in the curriculum, and the scoring of science and mathematics subjects. As illustrated in Table 1, for example, the number of teaching hours of mathematics in the science track were increased to five sessions/hours per week and the total score of this subject was increased from 100 to 125 points. However, in the social science track, mathematics was taught only three sessions/hours per week with a full score of 75.

**Table 1.** Comparison on the focus of science and social science track in Cambodia (grade 11<sup>th</sup> and 12<sup>th</sup>)

Subjects	Science Track			Social Science Track		
	Hour/week	No. Lesson	Max. Score	Hour/week	No. Lesson	Max. Score
Khmer Literature	3	59	75	5	69	125
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
History	2	15	50	3	24	75
Geography	2	24	50	3	24	75
Moral Studies	2	24	50	3	28	75
Earth/Environmental science	2	22	50	2	22	50

Consequently, according to the announcement number 11 of MoEYS (MoEYS, 2018a), from the academic year 2014, the students in the two tracks are required to take different subjects for their baccalaureate examination, see Appendix. As evidence, while the science track took mathematics, and all science subjects—biology, chemistry, and physics; their social science counterparts need to take only mathematics and possibly one lucky-draw-selective science subject. While the lucky-draw-selective social subject for 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 2018 respectively. This would be a crucial foundation, especially for the students in science track, to enrol in STEM majors in higher education as some studies (e.g., Woolnough, 1994; Seymour & Hewitt, 1997; Erdogan & Stuessy, 2015; Sahin et al., 2017) claimed that taking science and mathematics courses and attaining a high achievement in science and mathematics subjects by the students in the science track in the upper secondary school was an influential predictor of students' pursuit of STEM related majors at higher education.

Most of note, aiming to produce more students of high competency, knowledge, and expertise in order to develop both the economy as well as the overall strength of society, MoEYS has recently developed the so-called New Generation School. The main goal of this school is to improve educational quality throughout the entire education system especially science and mathematics related subjects at upper secondary school. According to MoEYS (2016c), though it is a pilot school, the New Generation School was aimed to greatly enhance the presence of educational innovation throughout the school system that empower the Cambodia's education system to effectively compete with other education systems to produce the workforce with 21<sup>st</sup> Century skills. Thus, more specific than the normal/traditional upper secondary school, the goal of New Generation School is to increase skill levels in STEM subjects at upper secondary school through intensive capacity building in educational technology and STEM and problem-based learning methodologies. As evidence, 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, see appendix. This ultimately aimed to increase more students' enrollment in STEM related fields in higher education.

Currently, according to the Human Capital Report 2015 of the World Economic Forum, the share of students in STEM related majors out of the total enrollment in higher education is about 18%, of which 9% is in science, 3% in engineering, 3% in medicine and health, and 2% in agriculture majors (JICA, 2016). More specifically, according to MoEYS (2016b) and the National

Employment Agency [NEA] (2018), there are not enough graduates in physical science, engineers, technicians, and industrial and production engineers, to name a few, to meet labour demand. Thus, to deal with this issue on a temporary basis and to encourage higher education institutions to pay more attention to STEM related majors such as mathematics, natural sciences (including physical sciences and biological/agricultural sciences), engineering, engineering technologies, and computer/ information sciences, MoEYS has been suspending the issuance of licenses to open new programs and courses related to accounting, banking, finance, management, and business—non-STEM related fields (MoEYS, 2014c).

In the other direction, with the introduction of policy on public-private partnerships (privatization) in higher education in 1997, the number of HEIs has been increasing from 18 in 1997 to 118 in 2016 (Mak, 2012; MoEYS, 2016b). Currently, these number of HEIs could admit the net enrollment of about 12% of the youth-age cohort into higher education sector (RGC, 2017) to reasonably serve the economic development need. Further, the number should be expanded to increase more access to higher education learning and to diversify the country economic development in this knowledge-based economy. Moreover, MoEYS has also encouraged and established more higher education institutions offering programs in STEM related fields. More statistically, as can be seen in Table 2, according to JICA report (2016) and MoEYS (2016b), among these 118 HEIs there are 52 institutions currently providing STEM related majors, of which 16 are national institutions and 36 are private. Of the 16 national institutions, 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 province. This also indicates the role of not only national universities but also private ones in offering STEM related fields geographically across the nation. Also, within these 52 higher education institutions, there are a total of 110 faculties and departments of STEM related fields. This even provides more diversity for students wishing to pursue their degrees in STEM fields in higher education.

**Table 2.** Number of HEIs offering STEM related majors in Cambodia

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

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

More practically, MoEYS and the British Embassy in Cambodia have recently published *STEM Career Booklet* listing potential STEM careers and Higher Education Institutions (HEIs) offering STEM related majors in Cambodia to afford upper secondary school students the chance of better orientation and help them make more well-informed choice in matriculating into STEM fields (British Embassy, 2016). Also, aiming to increase the students' interest in persisting into STEM related majors at higher education, some other extant extracurricular activities such as STEM bus (to bring science experiment to students) and Science and Engineering Festival (to raise public awareness of STEM) have been conducted, yet the effects of these programs are greatly underrated.

### 3.2 Issues

To raise the country economically, there is a drive to raise STEM education, especially at higher education level, across the country in order to bridge the skills gap as Cambodia shifts its economic focus into new realms (Mark, 2016; RGC, 2015; Un, 2012). Cambodia's education system is now beginning to recover from the Khmer Rouge period, suffering from a lack of qualified teachers in general and more qualified teacher in science subjects in particular and insufficient facilities. However, the causes of this skills gap are not a mystery. This is well-understood by the Royal Government of Cambodia, and thus significant reforms at the Ministry of Education, Youth and Sport (MoEYS) have made progress towards addressing these challenges, particularly in promoting students' participation in STEM related majors at higher education, yet much remains to be done.

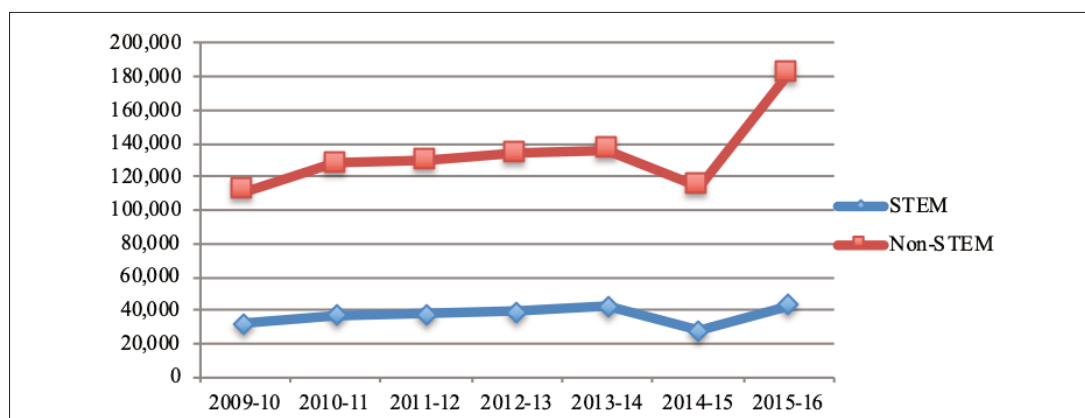
First, according to Cambodia's National Science and Technology Master Plan 2014–2020 (RGC, 2013b), Cambodia has only 17 science and technology researchers and 13 technicians per million of its population. This is low compared even to other countries in the region. Since Cambodia's social awareness of and competitiveness in science, technology, and innovation are generally low, students tend to avoid natural science and engineering. As evidence, according to CDRI (2015), it was revealed that college graduates specializing in business, finance, foreign languages, and liberal arts account for more than 70% of the Cambodian higher education graduates. This alarming trend of largely business-related graduates is creating a surplus in job seekers in that sector and a shortage of skilled personnel in STEM sectors (CDRI, 2015; Kaing, 2016). More seriously, according to World Economic Forum (2018), Cambodia was ranked 86<sup>th</sup> among 100 comparator countries with regards to having skilled human resource in digital, science, and management ready for the industrial 4.0 revolution. This indicated the low science and technology

readiness among Cambodian for both science and mathematics education and the current need of the current industrial development.

Secondly, there is also not enough elementary, intermediate, and highly educated manpower in science and technology. For example, telecommunication engineers, industrial and production engineers, chemical engineers, and even electronic engineering technicians, are highly sought after in the labour market since the supply is low (JICA, 2016; MoEYS, 2013; NEA, 2018). According to Mark (2016), there are some issues that need to be taken into consideration with respect to the lack of highly educated human resource in STEM related majors. These include the students' misunderstanding and negative perception on the jobs in STEM fields. Careers centred around office work such as banking, finance, accounting, and business are the dominant choices of university students. These are perceived by many students to be well-paid and high-status careers in society; however, STEM related careers were perceived to be hard-work (outside air-conditioning working environment) ones. It is even stated that there is much parental influence in terms of prejudices in jobs. When students wanted to pursue STEM professions, parents, extended families, and significant others had a large influence. Parents often made the final decision, and little data have been collected about what parents know about STEM professions; however, it has been reported that parents, as their embedded mindset that STEM related careers are outdoor male dominated occupation, would prefer their children especially female to pursue majors with rewarding career prospects (Kao, 2013; Kaing, 2016; Mark, 2016; RGC, 2013b).

The quality of general education in general and science and mathematics in particular remains a key concern when considering the high rate of enrollment in STEM fields. At lower secondary school, 87.4% of the students passed out from primary level (Chey & Khieu, 2017). Chhinh, Edwards, Williams, and Yu (2015) indicated that the recent policy reform of the national exit examination at upper secondary school has focused on the strong effort of the RGC to eliminate or/and to stop irregularities such as cheating, and leakage of examinations. Under strict examinations, only 40% of the students were capable to pass the national exit examination, as compared with passing rates of approximately 80% in the past decade (MoEYS, 2014d). The achievement in mathematics and science is even of great concern. For example, during the 2015 national examination, out of 83,325 students, only 23.3% passed the math portion, while 41.7% passed the biology portion. In similar vein, it was also shown that though human resources in STEM fields is significant for the country development, the lack of qualified teachers for science and mathematics at upper secondary school, the lower interest and attitudes of the students towards science and mathematics, and poor teaching and learning facilities at upper secondary school is yet a major concern to enhance STEM enrollment (MoEYS, 2016a).

As consequence of this low awareness of, attitudes towards, and achievement in science among Cambodian upper secondary school students, CDRI (2018) reported that while the number of students in higher education institutions increased from 13,461 in 1996 to 219,069 in 2016, or from 1% to 12% of the youth-aged cohort, fewer than 20% of them majored in engineering and science. In post-graduate courses, less than 10% of the students major in STEM, which highlights the imbalance in students' majors (ADB-ILO, 2015). In line with this, JICA (2016) further emphasized that the lack of STEM related graduates is hindering the diversification and modernization of the industrial structure of Cambodia. Currently, due to the lack of a skilled labour force in STEM fields, industries are forced to incur significant costs in, for example, bringing foreign engineers to Cambodian factories.



**Figure 2.** Share of graduates in STEM and Non-STEM related majors from 2009–2016

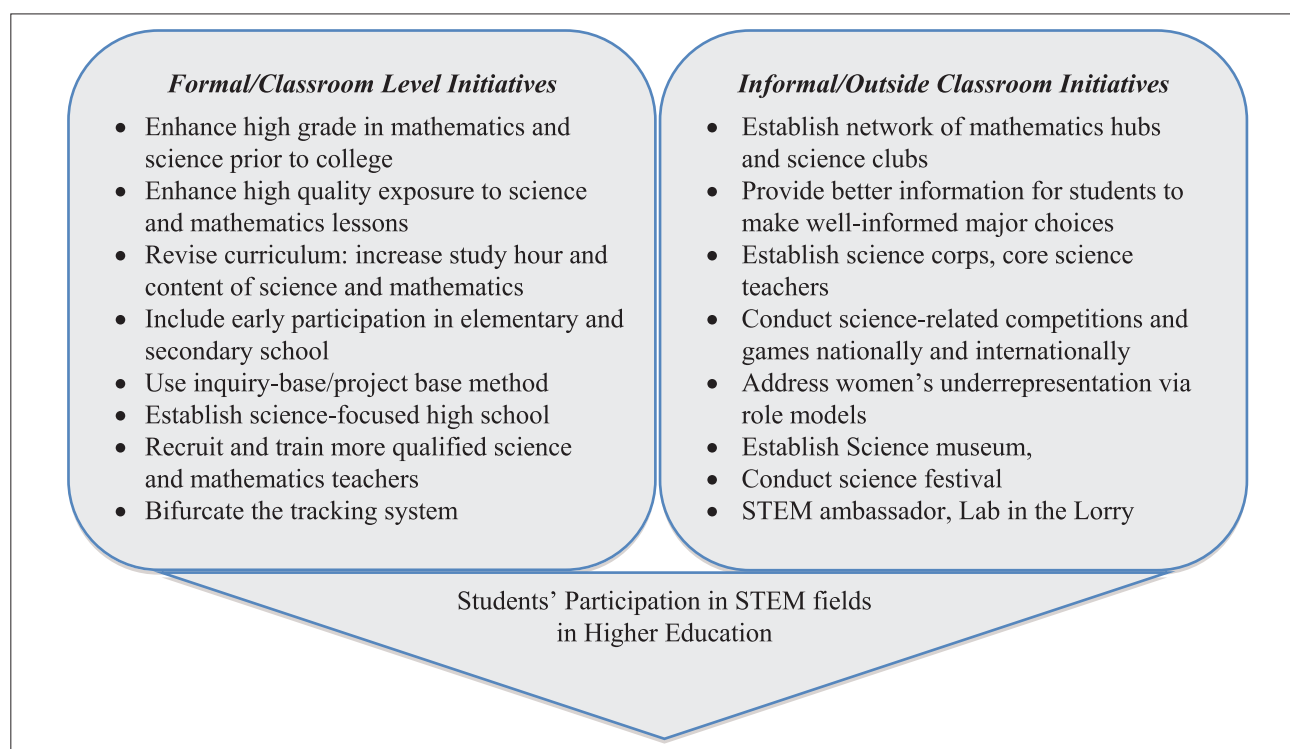
**Source:** Statistics compiled by Department of Higher Education from 2010–2016, MoEYS (2016)

To transform Cambodia's status from a lower-income country to a higher middle-income country, skills improvement of existing workforce and those who are prepared to enter the workplaces is crucial. Through this mechanism, the number of low-skilled workers would be reduced, while the low number of medium and high-skilled workers would be increased (RGC, 2017; Un,

2012). In this regards, middle and high skill graduates in STEM fields is currently much in needed. However, as can be seen in Figure 2, there is an imbalance between the shares of enrollment in STEM and non-STEM related fields. While upper secondary school level enjoyed a higher share of students in the science track than in the social science track, higher education level of Cambodia has experienced a mass enrollment in and an oversupply of graduates in non-STEM fields such as business, management, economics, humanity, and accounting. Surprisingly, this indicates a worrisome-disconnect between students' interests in and attitudes towards science from upper secondary school to higher education in STEM related fields.

### 3.3 Implications of Initiatives

Flourishing STEM education especially in higher education is indispensable to long-term economic growth and stability. The issues pertaining this low uptake in the field, thus, should not be overlooked. To address the issues of low participation in STEM fields or shortage of graduates resulting from the decline of interest in and lower attitudes towards science studies, effective initiatives and strategies implemented in the other countries merit being taken under consideration in the Cambodian context. Figure 3 illustrates the synthesis of the review on the extant implications of initiatives implemented to increase the share of the students matriculated from science track/stream at upper secondary school into STEM major in higher education of the target countries. A few steps were taken to visualize the figure. First, direct content analysis method (Creswell & Poth, 2017) was employed to analyze STEM country comparison reports of the comparator countries. Then, the common initiatives (counting frequency of codes) were coded as common themes. Finally, the common themes were then classified (based on the implementation approach) into emerging themes: formal/classroom level initiatives and informal/outside classroom initiatives, see Figure 3.



**Figure 3.** Synthesis of initiatives implemented to enhance students' participation in STEM fields.

**Source:** Developed by Authors

From the analysis of policy documents and literature on initiatives and strategies implemented in five OECD nations to raise students' competence and interest in science and to enhance upper secondary school students' uptake in STEM fields in higher education, there is a diversity of initiatives. However, based on the nature of the approaches that the initiatives took and from the thematic analysis, the implications of initiatives were classified into two main categories: Formal/Classroom Level and Informal/Outside Classroom initiatives.

### 3.3.1 Formal/Classroom Initiatives

First, in all strong STEM comparator countries, broadening science and mathematics engagement and achievement entails improving participation in STEM disciplines through initiatives covering the full spectrum of prior student achievement. Many countries, such as France, Japan, and the United States have enhanced science and mathematics education at secondary level via major revisions of the curriculum to increase the study hours and contents of science and mathematics prior to the transition into higher education STEM (European Commission, 2011; Ishikawa, Fuji, & Moehle, 2013; National Science Board, 2016; Oliveira & Roberts, 2013). Moreover, responding to the demands from students and so as to build a stronger background in science and mathematics, “Triple Science” was implemented in the United Kingdom. The key purpose of this policy initiative is to increase students’ exposure to interesting science and mathematics lessons, which was found to be a potential foundation for students’ stronger science and mathematics achievement and greater participation in science-related majors in higher education (Department for Business, Innovation and Skill, 2014). Thus, not only teaching contents but also how to effectively transfer the contents to the students lie within the policy initiatives of the comparator countries.

Many comparator countries with strong STEM agendas and results have a well-developed upper secondary school curriculum, the curriculum that focuses on building students’ innovation, creativity, and reasoning skills. In relation to this school curriculum, teachers and teaching methods could also be addressed through, in a nutshell, a core of learning and teaching methods based on problem solving, inquiry, critical thinking, and creativity all of which could enhance not only students’ attitudes towards but also practical competency in STEM related fields (Marginson et al., 2013; Erdogan & Stuessy, 2015; Sahin, Ekmekci, & Waxman, 2017). In addition, some comparator countries have targeted recruiting and training more science and mathematics teachers to make teaching more attractive and to attract and encourage more students into STEM fields (National Science Board, 2016).

Moreover, most of the comparator countries in this review achieved strong participation in STEM related fields through a bifurcation between science (STEM) and social or humanity (non-STEM) tracks at upper secondary school (Marginson et al., 2013; Paik & Shim, 2013). The tracking system has been found to have an impact on increasing students’ uptake in STEM in higher education (Marginson et al., 2013). This is due to the fact that students in the science track are usually exposed to more advanced science and mathematics courses—pre-university preparation. On a broader scale, some countries have even set up science-focused high school (the *Super Science High School* in Japan, the *National College for Key STEM Sectors* in the United Kingdom, and *STEM high School* in the United States, for example) to train the best and the brightest STEM talent with a so-called elite science education. However, in Cambodian context, since the beginning of its implementation in 2010, though science track has attracted many upper secondary school students, students’ uptake into STEM fields in higher education is very limited. This led to a further investigation of how science and mathematics is taught and learnt in science track with respect to building students’ science and mathematics competence, enhancing their interests in science, and developing positive attitudes towards science and participation in STEM fields in higher education.

### 3.3.2 Informal/Outside Classroom Initiatives

Besides these formal initiatives, to enhance students’ interest in and attitudes towards science, the comparator countries have also implemented other practical outside classroom activities including science center, later become science museum (European Commission, 2011), science festivals (e.g., the United Kingdom and France), science competitions (e.g., the United Kingdom, Japan, and France), mathematics and science clubs (e.g., Japan and the United Kingdom), science corps and STEM ambassadors (e.g., Japan and the United Kingdom), and Lab in the Lorry (e.g., the United Kingdom and the United States). The science center which has been established mainly since the 1960s in some European countries is a new form of science museum that emphasizes hands-on approaches and interactive exhibits that focus on scientific topics that have significantly encouraged visitors to take a playful yet critical approach to scientific topics (European Commission, 2011). It was found that students who had been to science centers or science museums were being more motivated in their choices of science related majors in higher education.

Moreover, in addressing the long-discussed issue of the underrepresentation of women in STEM fields, some comparator countries have implemented mentoring programs that have been positively evaluated as improving women’s participation in these fields. A few of these various ways were to bring together young women and successful female STEM professionals to provide an authentic understandings of STEM careers and access to female role models (Marginson et al., 2013). In fact, a similar trend is being implemented in Cambodian context to promote the public awareness of future STEM careers; female role models were also highlighted in the STEM Career Booklet (British Embassy, 2016). However, broader mentoring programs should be employed in the particular form of peer-to-peer supports that include successful STEM professionals to share their authentic experiences with female students.

Furthermore, to enable pupils and students to carry out hands-on activities, the United Kingdom, in particular, provided the so-called mobile science lorry to visit a number of high schools during the school year, irrespective of their location. This mobile



science lorry—the “Lab in the Lorry”—takes hands-on experiments to students in upper secondary school across the nation (European Commission, 2011) to increase their understanding and inspiration to pursue science-related fields. Program in a similar vein has also been implementing in the Cambodian context. With the support of the British Embassy in Cambodia, MoEYS has been implementing the so-called STEM Bus. The bus aimed at mainstreaming, promoting, and enhancing STEM knowledge applications as well as raising and promoting enthusiasm for studying STEM fields from general education to higher education. This mobile vehicle is also used to exhibit science expositions as well as to promote awareness of and interest in STEM fields at upper secondary schools in the capital and provinces across the country (MoEYS, 2018b).

The afore-mentioned initiatives focus on building students’ interests in and attitudes towards science subjects in upper secondary school and increasing their confidence and encouragement to pursue science or STEM related fields in higher education. Perhaps under the influence of the British Embassy in Cambodia, some similar activities have also been conducted in Cambodian context. For instance, in order to promote students’ interests in and public attitudes towards science, technology, engineering, and mathematics (STEM) in higher education, the so-called STEM Festival has been held annually (MoEYS, 2018b). However, the effects of these initiatives on Cambodian students’ uptake into STEM fields in higher education has yet to be determined. Also, this festival is usually conducted in Phnom Penh which, thus, limited the accessibility of many students in the provinces.

#### 4. Conclusion and Implications

As Cambodia is aiming to shift the country’s economic focus to an industrial-based economy and to move from a lower-middle income country to a higher-middle income country by 2030 and a high-income country in 2050, qualified human resources in STEM related fields must play significant role especially in this knowledge-based society of industrial 4.0 era. Judging from current trends and future projections, the shortage of graduates in STEM fields is a critical issue that needs to be addressed. Though a higher proportion of student has shown strong interests in science and mathematics at the upper secondary school level, their interests declined as they proceeded to higher education level. This trend has drawn attention to the key issue of achievement in science and mathematics which might consequently contribute to the shortage of graduates in STEM fields to meet the current and future career prospects and the need of workforce with 21<sup>st</sup> century skills. Based on the synthesis of policy initiatives the current study pointed out that, to better address the alarming issue of low STEM enrollment at higher education, policy initiatives at upper secondary school such as increasing achievement in science and mathematics and exposing students to more interesting science and mathematics lessons to cultivate their initial interests in science and mathematics should be given higher priority. This could be done through enhancing the quality of science and mathematics learning and teaching. Thus, teachers’ professional development (mathematics and science teachers) and more effective teaching methodology such as project-based learning and inquiry-base learning (as found here) should be considered not only at upper secondary level but also from the earlier education level. Increasing only teaching hour in the current science track would not make much difference without considering new teaching methods. Furthermore, extracurricular initiatives (outside classroom initiative) should also be strongly considered. This paper suggested that large-scale initiatives such as establishing science museum, holding science festival at school level, conducting science competition, and implementing science and mathematics club, and lab in the lorry should be contextualized in Cambodia. The implementation of any of these initiatives and the modification of the existing ones, to whatever extent, should be significant for MoEYS in realizing its STEM Education Policy and in promoting greater student participation in STEM fields in higher education. Ultimately, the critical demand for human resources in STEM fields to support the realization of the Industrial Development Policy of the Royal Government of Cambodia in this knowledge-based economy would be addressed.

#### Acknowledgement

The authors would offer special thanks to the People of Japan in general and Japan International Cooperation Center (JICE) in particular for the scholarship offered.

#### References

- ADB-ILO. (2015). Cambodia: *Addressing the skills gap*. Mandaluyong City, Philippines: Asian Development Bank.
- Asian Development Bank [ADB]. (2011). Improving instructional quality: Focus on faculty development. *Higher Education in Dynamic Asia*.
- 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.
- Bryman, A. (2016). *Social research methods*. Oxford university press.
- Cambodia Development Resource Institute [CDRI]. (2015). *Cambodia education 2015: Employment and empowerment?*
- Cambodia Development Resource Institute [CDRI]. (2018). *Cambodia development research forum (DRF) symposium 2018: Post-secondary education development through multi-stakeholder engagement*. Phnom Penh, Cambodia.
- 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., & 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., & Jacob, W.J. (Eds). *The Political Economy of Schooling in Cambodia. Issues of Quality and Equity. Introduction. Palgrave Macmillan*, 3-11.
- Creswell, J. W., & Poth, C. N. (2017). *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.
- Department for Business, Innovation and Skill. (2014). *Our plan for growth: Science and innovation*. UK.
- 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.
- European Commission. (2011). *Science education in Europe: National policies, practices, and research*. Education, Audiovisual, and Culture Executive Agency.
- Freeman, B., Marginson, S., & Tytler, R. (Eds.). (2014). *The age of STEM: Educational policy and practice across the world in science, technology, engineering and mathematics*. Routledge.
- Green, M. (2007). Science and engineering degrees: 1966-2004. *Virginia: National Science Foundation*.
- Ishikawa, M., Fuji, S., & Moehle, A. (2013). *STEM country comparison: Japan*. Retrieved May 01, 2018, from <https://acola.org.au/wp/stem-consultants-reports/>.
- 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.
- Kaing, S. (2016). *How can STEM education help stimulate economic growth in Cambodia*. (Unpublished Master's Thesis). Vrije Universiteit, Brussel.
- 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 Cambodia.
- Maltse, 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.
- Mark, O. (2016 February 17). *Cambodia's skill challenge: Bridging the gap*. Retrieved May 12, 2016, from The Cambodia Daily: <http://www.cambodiadaily.com>.
- Ministry of Education, Youth and Sport [MoEYS]. (2009). *Announcement 09 dated 10 July 2009 on subjects required in the entrance examination for the foundation year program for the first year of the bachelor's degree*. Phnom Penh, Kingdom of Cambodia.
- Ministry of Education, Youth and Sport [MoEYS]. (2010). *Announcement No. 23 on the implementation of the new curriculum in upper secondary education*. Phnom Penh, Kingdom of Cambodia.
- Ministry of Education, Youth and Sport [MoEYS]. (2013). *Report on the situation of science, technology, engineering, and mathematics education in Cambodian higher education institutions*. STEM Workshop, 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). *Education strategic plan 2014–2018*. Phnom Penh, 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]. (2014d). *Results of high school completion examination 1980–2013*. Phnom Penh: Ministry of Education, Youth and Sport, 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 enrollment in science and social science track in general education*. Department of General Education, Phnom Penh, Kingdom of Cambodia.
- Ministry of Education, Youth and Sport [MoEYS]. (2018a). *Announcement No.11 on the implementation of baccalaureate exam for academic year 2017–18*. Phnom Penh, Kingdom of Cambodia.
- Ministry of Education, Youth and Sport [MoEYS]. (2018b). *Education Congress report on the achievement for the academic year 2016-2017 and direction for 2017–2018*. Phnom Penh, Kingdom of Cambodia.
- National Employment Agency [NEA]. (2018). *Cambodia job outlook 2018*. Phnom Penh, Kingdom of Cambodia.
- National Science Board. (2016). *Science and engineering indicator 2016*.
- 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](https://acola.org.au/wp/PDF/SAF02%20Consultants/Consultant%20Report%20-%20France.pdf).
- Organization for Economic Cooperation and Development [OECD]. (2017). *Database on Education at a glance*. Retrieved May 30, 2018, from [https://stats.oecd.org/Index.aspx? datasetcode=EAG\\_ENRL\\_MOBILES\\_FIELDS](https://stats.oecd.org/Index.aspx?datasetcode=EAG_ENRL_MOBILES_FIELDS).
- 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.
- Royal Government of Cambodia [RGC]. (2013a). *“Rectangular strategy” for growth, employment, equity, and efficiency phase III*. Phnom Penh, Kingdom of Cambodia.
- Royal Government of Cambodia [RGC]. (2013b). *Cambodia’s national science and technology master plan for growth and quality of life*. Phnom Penh, Kingdom of Cambodia.
- Royal Government of Cambodia [RGC]. (2014). *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]. (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.
- 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.
- Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why do undergraduates leave the science?* Boulder, CO: Westview Press. USA.
- Tomei, A., Dawson, E., & Dillon, J. (2013). *A study of science, technology, engineering and mathematics education in United Kingdom*. Retrieved May 01, 2018, from <https://acola.org.au/wp/stem-consultants-reports/>.
- 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.
- UNESCO National Education Support Strategy [UNESS]. (2010). *UNESCO educational support strategies*. UNESCO, Phnom Penh, Kingdom of Cambodia.
- Un, L., & Sok, S. (2016). *Higher education governance in Cambodia*. Education Research Council, Ministry of Education, Youth and Sport.
- Weinrib, J., & Jones, G. (2013). *Canada’s approach to Science, Technology, Engineering and Mathematics (STEM): Context, policy, strategy and programs*.
- Woolnough, B.E. et al. (1997). Factors affecting student choice of career in science and engineering: Parallel studies in Australia, Canada, China, England, Japan, and Portugal. *Research in Science and Technology Education*, 15(1), 105–121.
- World Economic Forum [WEF]. (2018). *Readiness for the Future of Production Report 2018*. Geneva: WEF.

**Appendix:**

Subjects and weekly learning hours in social science track, science track, and New Generation School in Cambodia (Grade 11<sup>th</sup>-12<sup>th</sup>)

No.	Subject	Normal Upper Secondary School		New Generation School	Subject for Baccalaureate Examination	
		Social Science	Science	Science	Social	Science
1	Khmer Literature	5	3	5	C	C
2	Foreign Language	2	2	4	C	C
3	Physical Education	1	1	1	N	N
4	Mathematics	3	5	6	C	C
5	Physics	2	3	4	L	C
6	Chemistry	2	3	4	L	C
7	Biology	2	3	4	L	C
8	Earth Science	2	2	1	L	L
9	Geography	3	2	2	C	L
10	History	3	2	2	C	L
11	Moral Education	3	2	3	C	L
12	Economic	2	2	1	N	N
13	Technical Education (Elective)	2	2	4	N	N
<b>Total</b>		<b>32</b>	<b>32</b>	<b>40</b>	<b>7</b>	<b>7</b>

**Note:**

- C: Compulsory subject for baccalaureate examination
- L: Lucky-draw subject for baccalaureate examination
- N: Not included in baccalaureate examination
- One of the four lucky-draw subjects will be selected (at ministry level) as another compulsory subject for baccalaureate examination in each study track (total 7 subjects)